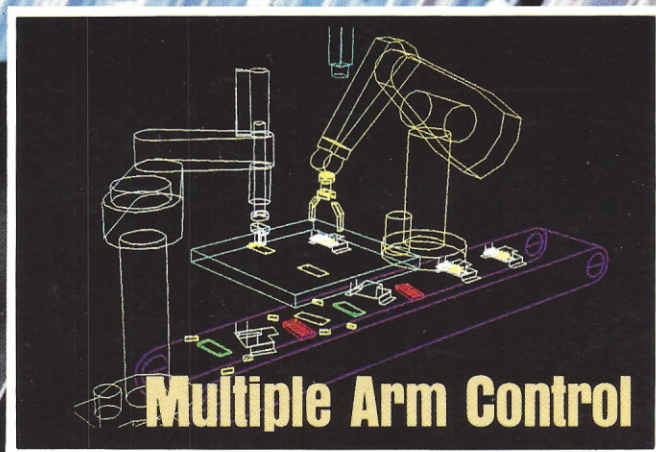


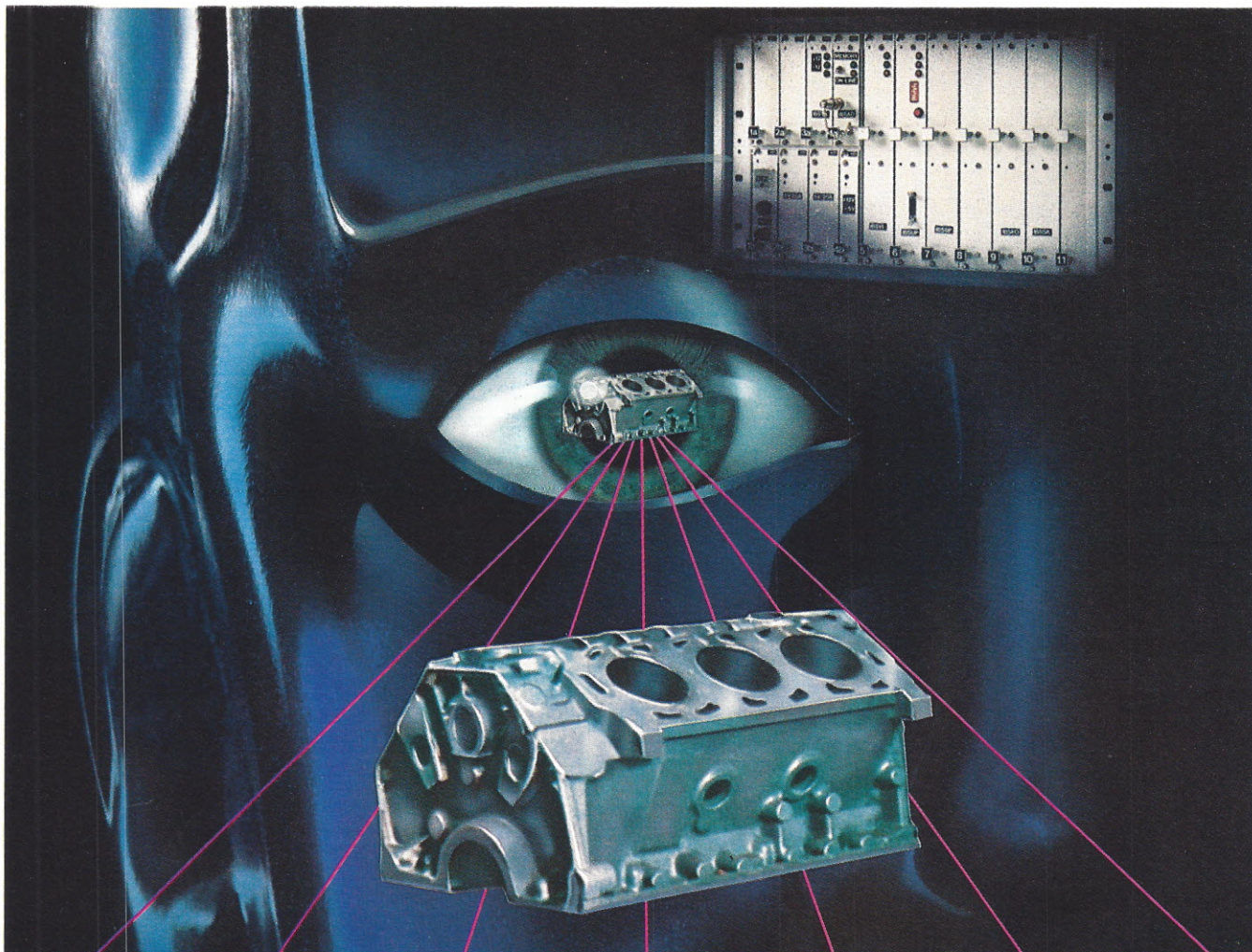
ROBOTICS

E N G I N E E R I N G

THE JOURNAL OF INTELLIGENT MACHINES



Robotics in Electronics Assembly
Robot Reliability: A User Speaks Out



**Multiprocessor
based robotics
controllers
with integrated
PLC; robot
guidance and
vision systems
...that's high
technology
from AEG!**

AEG believes that industrial automation should be simple, reliable, flexible and easy to operate. Our technology has made that belief a reality with the R-500 programmable robot controller.

The R-500 is a modular, distributive, multiprocessor based system which provides high speed computing power while remaining completely user friendly through its English text programming. The design includes linear and rotational motion control, vision systems interfaces and communications capabilities such as LAN, MAP and others.

This system provides a built-in integrated programmable logic controller (PLC) which eliminates the need for separate PCs and effectively provides total control of the workcell.

Our industrial vision system operates much like the human eye in that the camera is the functional equivalent of that organ which "sees" products on the line in gray-scale. Pre-processing is handled by the electronic interface while the vision controller, which is high speed multiprocessor based, performs the decision making processes. AEG firmware supports applications such as part recognition, inspection tasks and robot guidance. AEG is a worldwide source for technological innovation in areas which include not only robotics but, information systems, satellites, solar power, electronic packaging, power semiconductors, technical tubes and office systems.

For more information on our vision system and programmable robot controllers contact our Detroit office:

AEG Corporation
17177 North Laurel Park Drive
Livonia, MI 48152
(313) 591-2233.

For more information on our other high technology products contact our corporate headquarters:

AEG Corporation
Route 22-Orr Drive
PO Box 3800
Somerville, NJ 08876-1269
or call (201) 722-9800.

AEG

Publisher
Chris Crocker

Editor
Carl T. Helmers, Jr.

Associate Editor
Stephanie vL Henkel

Consulting Editors
Rakesh Mahajan
Robert E. Parkin, Ph.D.
Roberta Toth

Editorial Coordinator
Lorraine Cleveland

Production/Design Director
David Wozmak

Production Assistant
Ruth S. Wilder

Circulation Manager
James E. Bingham

Circulation Assistants
Deborah Louzier
Winnie Werth

Dealer Accounts
Meredith Makela

Typography
Sheryl Fletcher

Receptionist
Erin Cuddemi

Advertising Manager
Donna Louzier

Advertising Coordinator
Cheryl Wilder

Advertising Sales

Brian R. Beihl
Associate Publisher
Robotics Age Inc.
174 Concord Street
Peterborough, NH 03458
603-924-7136

Member of
Business Publications Audit



ROBOTICS ENGINEERING—(ISSN 0197-1905) is published monthly by Robotics Age Inc., Strand Building, 174 Concord Street, Peterborough, NH 03458, phone (603) 924-7136. Address subscriptions, changes of address, USPC Form 3579, and fulfillment questions to *Robotics Engineering* Subscriptions, 174 Concord Street, Peterborough, NH 03458. Second class postage paid at Peterborough, NH and at additional mailing offices. **POSTMASTER:** Send address changes to ROBOTICS ENGINEERING, 174 Concord St., Peterborough, NH 03458.

Subscriptions are \$24 for one year (12 issues), \$45 for two years (24 issues), \$63 for three years (36 issues) in the USA and its possessions. In Canada and Mexico, subscriptions are \$28 for one year, \$53 for two years, \$75 for three years. For other countries, subscriptions are \$32 for one year, surface delivery. Air delivery to selected areas at additional charges, rates upon request. Single copy price is \$3 in the U.S., \$3.50 in Canada and Mexico, \$4 in Europe, and \$4.50 elsewhere. Foreign subscriptions and single copy sales should be remitted in United States funds drawn on a U.S. bank.

Address all editorial correspondence to the Editor at *Robotics Engineering*, Strand Building, 174 Concord Street, Peterborough, NH 03458. Opinions expressed by the authors of articles are not necessarily those of *Robotics Engineering*. To aid in preparation of acceptable articles, an Authors' Guide is available upon request, if accompanied by a self-addressed 8½ by 11 inch envelope with first class postage for 3 ounces. Unacceptable manuscripts will be returned if accompanied by a self-addressed envelope with sufficient first class postage. Not responsible for lost manuscripts or photos.

16mm microfilm, 35mm microfilm, 105mm microfiche and article copies are available through University Microfilms International, 300 North Zeeb Rd., Ann Arbor, MI 48106.

Each separate contribution to this issue, and the issue as a collective work, is © 1985 Robotics Age Inc. All rights reserved. Copying done for other than personal or internal reference use without the permission of Robotics Age Inc. is prohibited. Requests for permission should be addressed in writing to *Robotics Engineering* Permissions, Strand Building, 174 Concord Street, Peterborough, NH 03458.

THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS

ENGINEERING

APRIL 1986

VOL. 8 NO. 4

EDITORIAL

2 Robots—The Reliability Issue

by Carl Helmers

FEATURES

6 Robotics: A User's Perspective

by R.J. Piccirilli, Jr.

7 An Interview with Richard E. Dauch

by Ben Nagler

Robots are not living up to manufacturers' performance specifications and user needs, according to the experience of at least one end user, the Chrysler corporation. The problems, and Chrysler's response to them, are outlined in two companion articles.

12 Justifying High-Tech Manufacturing Solutions Through JIT-TQC-CIM

by Ani D. Chitaley

Justification of high-tech manufacturing equipment is a strategic issue, due to increasing competition in the marketplace and the improving product process capabilities of high-tech business. A philosophy and a technique for modernization and justification of high-tech equipment are outlined.

18 Multiple-Arm Control and Assembly Operation

by Gordon Mayer
and Elaine Ide Wood

Integrated vision, integrated control, and extensive sensory communications can actually simplify a robotic assembly cell. An examination of two robots with overlapping work envelopes putting together an oil pump illustrates the benefits of total cell integration.

26 The Simulation and Programming of Multiple-Arm Robot Systems

by James F. Callan

Some complex assembly operations cannot be automated without the use of multiple, cooperating robot arms. Computer-based robot simulation systems can contribute a great deal to designing and debugging a multiple-arm workcell.

30 Case History of an Automated Assembly System

by Frank C. Romeo

Fierce competition in the electronics and communications industries is forcing profit margins down. Robotics offers a cost-effective edge in making the high-quality, low-price products the market demands.

DEPARTMENTS

- 4 Calendar
- 34 In The Robotics Age
- 35 Advertiser Index
- 40 New Products
- 44 Classified Advertising

About the cover: This month's cover photos were provided by Chad Industries and by Silma Incorporated. Silma's CimStation™ (above right) uses computer aided design to create and modify a 3-D model of one or more robotic workcells, write programs, and create computer graphic animation of the robots executing their programs. Chad's Model ECA 1101 parts presentation end effector is shown receiving a mix of standard and nonstandard printed circuit board components, which it will present to the insertion end effector for through-hole placement on the board. See related articles on pages 26 and 30.



Editorial

Robots—The Reliability Issue

BY CARL HELMERS

In an address to the annual meeting of the Robotic Industries Association this January, Robert J. Piccirilli, director of manufacturing engineering at Chrysler, brought to light a growing need: End users of robots must become more actively involved in the design, development, implementation, and, above all, the verification process of robots and robotic systems.

Chrysler's experience, it seems, has not been a happy one. Not one of the some 200 robots of both domestic and foreign manufacture the firm put to its 50-hour and 20-hour testing procedures performed according to manufacturers' specifications. Fifty robots broke down before actual testing began. The causes, Chrysler says, were design and manufacturing defects that came with the robots. (For an in-depth look

at the problems Chrysler has identified and the ways the firm plans to solve them, see the articles beginning on pages 6 and 7.)

Chrysler's position is that the end user should be neither surprised nor disappointed by the performance of a new robot—the device should be able to go straight from the receiving platform to the factory floor and do precisely what it was purchased to do immediately upon being set up and plugged in.

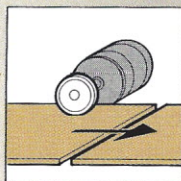
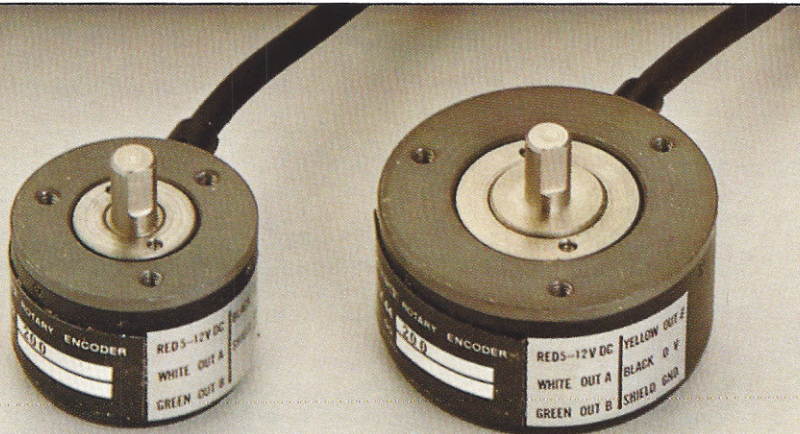
A certain amount of leeway must be given when applying any developing technology, because it is only through application that technology can develop. Robots, however, are no longer brand-new; a replacement market has already begun to emerge. And Chrysler, a substantial buyer and user of robotic technology, is saying that enough is enough and has come up with a user-defined specification of acceptable performance. Is there a need for a manufacture-independent organization to gather and provide essential information on comparability and performance of the robots offered in the marketplace?

The RIA, in a laudable attempt to increase its interaction with end user member companies, has announced its intention to strengthen ties with Robotics International of the Society of Manufacturing Engineers. The RIA has also begun to reconsider its definition of a robot, and, according to an RIA spokesman, any new definition created will take into account such technologies as vision and other sensor capabilities, along with automatic guided vehicles and other technologies that were only in their infancy when the current definition was developed. We hope that the RIA's new definition will reflect the fact that the robot, as an intelligent machine, is no longer solely applied to discrete parts manufacturing, that applications now extend into process control and material handling, among other areas.

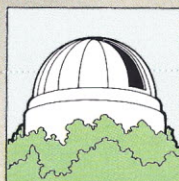
Chrysler's experience has led to the formulation of one vendor-independent set of verification tests for robotic products. The demand for such testing can hardly be limited to one corporation. We suspect that the entire robot end user industry is calling for the formation of some organization—or movement within an existing organization—to assure the purchasers of industrial robots that they can believe the manufacturers' product brochures and expect what they buy to live up to its billing.

The builders of robots must never forget that solving their customers' needs is paramount to the growth of their own industry. This is especially important in the application of robotics as a necessity for increased productivity, a higher-quality product, and improved human safety conditions. Why else would anyone buy a robot? ■

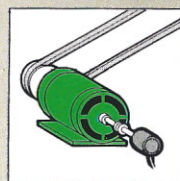
WHEN YOU NEED SHAFT ENCODERS SANDTRON'S GOT THEM



Length of cut control



Angular positioning



Speed control

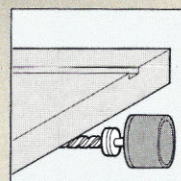


Table positioning

Sandtron supplies shaft encoders for all industrial, commercial and scientific applications. Sandtron's encoders give you a unique range of applicability without trade-offs — the high operating frequency of our encoders delivers resolution to 2048 lines even at high speeds with hysteresis feedback for jitter-free operation.

Sandtron encoders deliver top performance through a long life. All models are shock resistant and utilize precision ball bearings which ensure low activating torque and moment of inertia.

The small physical size of the REX encoders make them easy to mount even

in instrumentation applications. The REX 44 models are 44 mm (1.73 inches) in diameter and the REX 32 models are 32 mm (1.26 inches) in diameter.

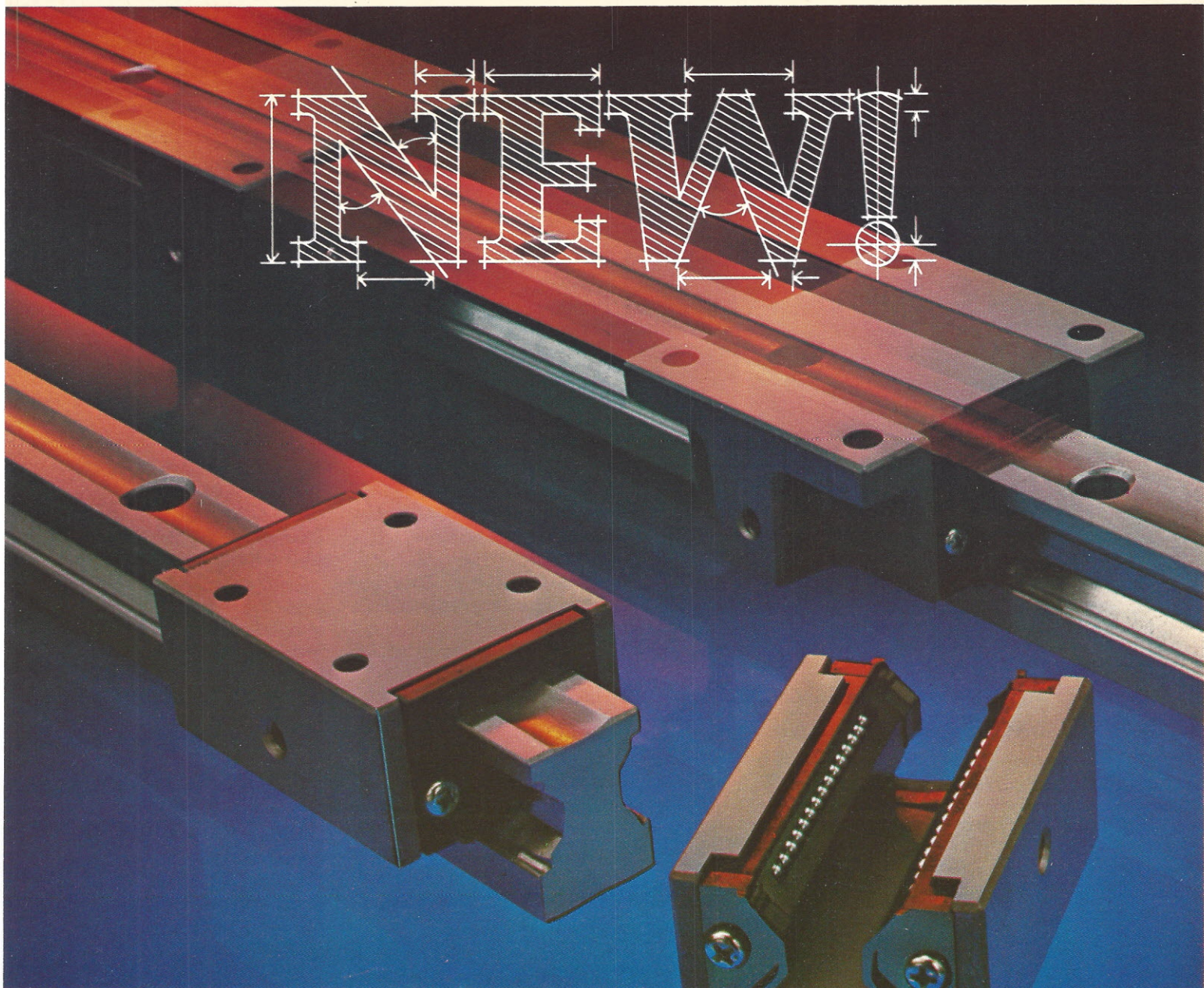
Call us today for complete information and design consultation.

Sandtron — sensing your needs.



RECHNER
electronics industries inc.

8651 Buffalo Avenue, Niagara Falls, N.Y. 14304
(716) 283-8744

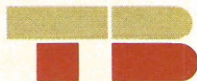
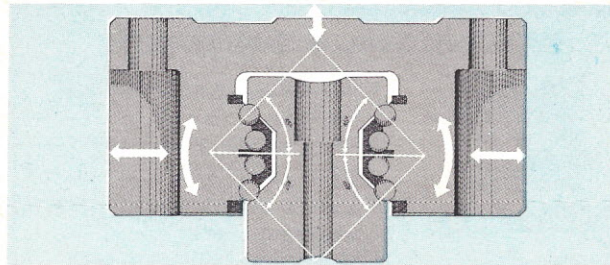


TychoTrax™ Linear Guideway A True Technical Advantage

Tychoway presents a new leader in precision: TychoTrax™ Linear Guideway. All the quality features you expect from a great precision company have come together to provide very high load capacity in several sizes—all in a simple compact design. The patented angular design provides equal capacity in all directions while circular arch ball contact gives minimum rolling differential slip.

TychoTrax™ Linear Guideway from Tychoway, the company with over twenty years of design and application experience in precision linear bearing products and systems.

For complete information write or call today: Tychoway Bearings Company, 9432 Southern Pine Blvd., Charlotte, NC 28210, (704) 523-2088 or toll free: 1-800-438-5983.



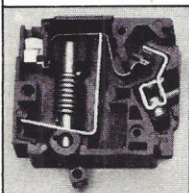
Tychoway Bearings Company

A Cross & Trecker Company

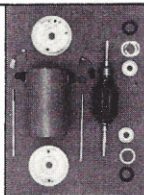
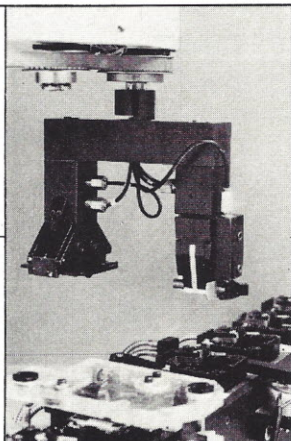
See us at **ROBOTS 10, Booth # 7069**

Circle 60

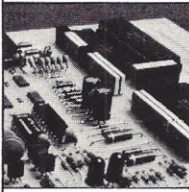
ROBOTIC SYSTEMS



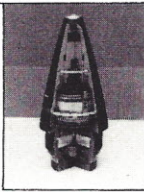
circuit breaker box



electric motor



printed circuit board



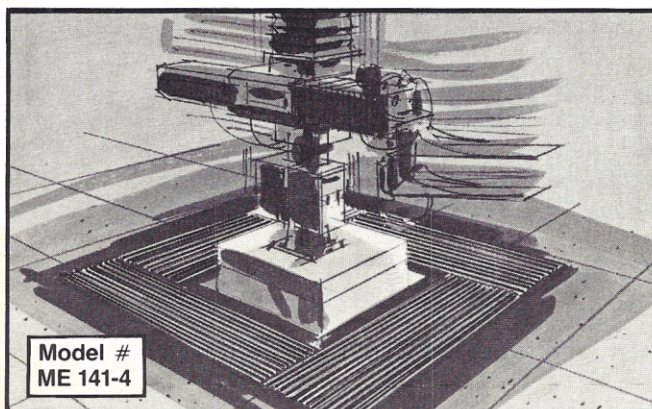
fuze

Flexible assembly systems including circuit boards, electro/mechanical devices, small motors, defense applications

Practical, proven turnkey installations nationwide, from single cell to CIM, utilizing 25 years of industrial automation experience. Call or write to

Advanced Development and Engineering Center

101 Chester Road • Swarthmore, PA 19081 • 215/544-7600



Model #
ME 141-4

GuardianMat Safety Switch

protects lives & equipment



MillerEdge

Visit us at
Robots 10 Booth #1060

- Failsafe construction for total reliability
- 100% flexible to withstand impact & resist damage
- Custom sizes & shapes to your exact specs
- Heavy duty non-skid surface resists common greases & oils

Call MillerEdge for free sample.

Concord Industrial Park, P.O. Box 38, Concordville, PA 19331
(215) 459-4241

Calendar

APRIL

1-3. **Manufacturing Productivity Conference and Exposition.** H. Roe Bartle Hall, Kansas City, MO. Contact: Public Relations Department, Society of Manufacturing Engineers, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-0777.

3-4. **Artificial Intelligence—An Applications-Oriented Approach.** Contact: Stod Cortelyou, The George Washington University, Washington, DC 20052, telephone (202) 676-6106 or (800) 424-9773.

7. **Semiconductor Equipment Communications Standard Seminar.** Phoenix, AZ. Contact: Jack Ghiselli, GW Associates, Inc., 645 Mills Ave., Los Altos, CA 94022, telephone (415) 948-2896.

7-10. **1986 IEEE International Conference on Robotics and Automation.** San Francisco Hilton & Tower, San Francisco, CA. Contact: Robotics & Automation, c/o Harry Hayman, 738 Whitaker Terrace, Silver Spring, MD 20901, telephone (301) 434-1990.

7-11. **IEEE Computer Society Tutorial Week.** Orlando Marriott Hotel, Orlando, FL. Contact: Director of Tutorials, IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903, telephone (202) 371-0101. (To be repeated 12-16 May at the Fairmont Hotel, Dallas, TX; 9-13 June at the Quality Inn Pentagon City, Arlington, VA.)

8-10. **Instrumentation '86—Pacific Northwest Conference and Exhibit.** Red Lion Inn, Lloyd Center, Portland, OR. Contact: Duane Schroeder, Publicity Chairman, Control Elements, Inc., 1730 S.W. Skyline Blvd., Portland, OR 97221, telephone (503) 297-1533.

8-10. **1986 Test & Measurement World Expo.** San Jose Convention Center, San Jose, CA. Contact: Meg Bowen, Conference Director, Test & Measurement World Expo,

199 Wells Ave., Newton, MA 02159, telephone (617) 964-8900.

8-10. **15th Annual International Programmable Controllers Conference and Exposition.** Cobo Hall, Detroit, MI. Contact: Carmelita Smirnes, Media Relations Coordinator, Engineering Society of Detroit, 100 Farnsworth Ave., Detroit, MI 48202, telephone (313) 832-5400.

9-12. **CommunicAsia 86.** World Trade Centre, Singapore. Contact: Gerald G. Kallman, Five Maple Court, Ridgewood, NJ 07450-4431, telephone (201) 652-7070.

9-16. **Industrial Automation '86.** Independent exhibit sector of Hannover Fair '86, Hannover, West Germany. Contact: Hannover Fairs USA, Inc., PO Box 7066, 103 Carnegie Center, Princeton, NJ 08540, telephone (609) 987-1202.

15-17. **First International Conference on Product Design for Assembly.** Newport, RI. Contact: Donna White, Conference Registrar, Troy Conferences, 134 W. University Dr., Suite 110, Rochester, MI 48063, telephone (313) 656-2195.

16. **Computers and Expert Systems for Welding Operations.** Annual Convention of the American Welding Society, Atlanta, GA. Contact: Rosalie Brosilow, Editor, *Welding Design & Fabrication*, 1111 Chester Ave., Cleveland, OH 44114, telephone (216) 696-7000.

16-18. **Electronic Systems Orientation For Fluid Power Sales Specialists.** Milwaukee School of Engineering, Milwaukee, WI. Contact: Cynthia Peck, National Fluid Power Association, 3333 N. Mayfair Rd., Milwaukee, WI 53222, telephone (414) 778-3356.

21-24. **ROBOTS '86.** McCormick Place, Chicago, IL. Contact: Robotic Industries Association, PO Box 1366, Dearborn, MI 48121, telephone (313) 271-7800.

Continued on page 44.

ROBOTIC WORK CELLS
COMPUTER CONTROL • AS/RS
TRANSPORT SYSTEMS
INSPECTION • VISION • TEST • SPC
NETWORKS • SIMULATION

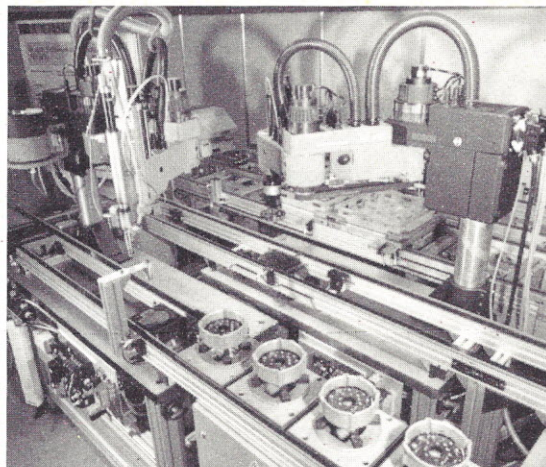
We do it all

...because we're an automation systems integrator

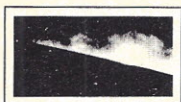
As your sole systems integrator, we make no secret about our formula for success: to provide complete turnkey automation systems on time. Period.

We do it all. All the engineering. All the integrating. We assume complete responsibility and handle every step to make your automation system perform *all* the necessary operations, from assembly through packaging. The "factory of the future" is no longer the theme for some trade show. Weldun is doing it today — and setting the standards others are trying to meet.

Let's get together and talk about your system. *All* of it.



This section of an automation system for assembling automotive alternators is typical of the kind of system we're capable of integrating. It is a flexible assembly system constructed of pre-engineered modular components, including Bosch transport lines. In the three stations shown here, several assembly operations are automatically performed by the three- and four-axis SCARA arm robots.



WELDUN

Flexible Assembly Systems

Division of Weldun International
Bridgman, Michigan 49106
(616) 465-6986

Single-source responsibility for total automation systems

Robotics: A User's Perspective

This material was excerpted from an address to the Robotic Industries Association given by R.J. Piccirilli, Jr. at the RIA's annual meeting on January 30, 1986 in Scottsdale, Arizona. For an expanded discussion of Chrysler's robot performance requirements and its testing program, see the accompanying interview with Richard E. Dauch, beginning on page 7.

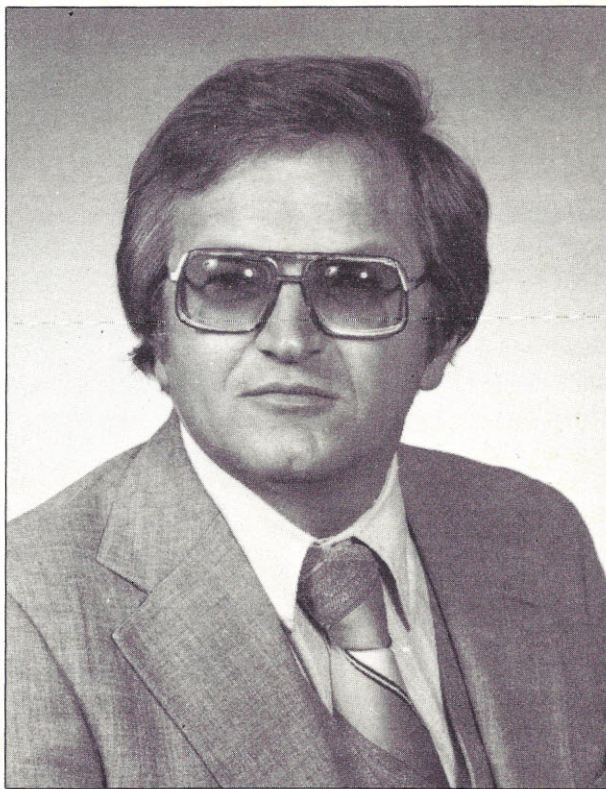
Aggressive application of robotics, along with other actions, has had a dramatic impact on Chrysler's quality and productivity performance. From 1980 to 1985, our quality, as measured by the number of quality defects per 100 vehicles reported by our dealerships, improved by 42 percent.

Quality and productivity go hand-in-hand. Improved quality brought these dramatic improvements in productivity:

- Vehicle production jumped from 4000 to about 8000/day.
- Vehicles produced per employee grew from about 10 to about 19.
- Six stamping plants were compressed into three.
- Steel inventories at stamping plants shrank from 41 days to 9 days.
- Most important, profit generation went from -\$10 million/day to +\$10 million/day.

These quality and productivity gains came through careful planning and using the four M's of manufacturing—manpower, methods, materials, and machinery. Using robots has been a big factor in attaining these results.

Chrysler must improve its performance still further. We estimate we are still wasting \$3.7 billion/year—some 20–25 percent of our sales revenue—because we are not



R.J. Piccirilli, Jr., Director of Manufacturing Engineering, Chrysler Corporation.

defect-free in our operations. We call it the *cost of quality nonconformance*. In short, this \$3.7 billion is the cost of *not doing the job right the first time* throughout the corporation and our supplier corps, including our robot suppliers.

While still relying on new technologies and processes to raise quality and cut

costs, the culture within both Chrysler and its robot suppliers has to change from a "get better" mindset to one that says *no level of defect is acceptable in any operation*. The robot industry is expected to play a major role in helping Chrysler implement this philosophy—through a systematic, step-by-step quality improvement process (QIP) based on four principles:

- The definition of quality is *consistent conformance to requirements*. Everyone must fully understand and conform to the customers' requirements.
- The quality system must stress preventing quality problems rather than detecting problems after the fact.
- The performance standard is to be defect-free.
- The quality measurement will be the cost of quality nonconformance.

We will attack the problem through:

- visible and ongoing management commitment
- local quality-improvement teams
- awareness—sharing experiences and recognizing achievements
- education—all must understand their individual and collective roles in managing the process

We Need Reliable, Ready-To-Use Robots, Not Fix-It Later Kits!

An Interview with Richard E. Dauch

Ben Nagler

Advanced Technology Communications
2336 Loyola Road
Cleveland, OH 44118

Trade associations' annual meetings can be nothing more than pep rallies or excuses for tax-deductible vacations at exotic resorts. While attendees at the Robotic Industries Association's annual meeting, held this past January in Scottsdale, Arizona, got both, they also got an earful of complaints from a major robot user—Chrysler Motors.

In a presentation remarkable both for its candor and its detail, Robert J. Piccirilli, Jr., Chrysler Motors' director of manufacturing engineering, first spelled out the importance of reliable robots to his firm's operations and profitability, and then told of shocking failures in robots supplied to them. (Highlights of Piccirilli's remarks appear in the accompanying article.) In a subsequent exclusive interview, Chrysler's Richard E. Dauch, executive vice president of manufacturing, provided cogent insights into other factors making for successful robotic applications.

Why did you choose the Robotic Industries Association's (RIA) annual meeting to publicize your new robot standards?

We, at Chrysler, found we were not getting the repeatability we expected in a robot—as it was expected to accomplish a given task. So I asked my people to tell me what they think quality really is—to see



Richard E. Dauch, Executive Vice President of Manufacturing, Chrysler Corporation.

if we, the auto industry, as the customer for 60 percent of the robots being sold, have properly defined to the robot manufacturers what our requirements are. I [also felt we ought to work] with RIA [since it] establishes the industry standards and is also, of course, the promotional arm for the robotics industries. When I got into

it, I found that their Standards Committee was not chaired by a user. They have seven [standards] subcommittees, one of which is called "Performance," and none of those seven subcommittees was chaired by a user: they were all chaired by manufacturers of robots! But *who* is the customer? The manufacturer is not the customer: the *user* is the customer.

It is my recommendation that RIA reconsider having a user—especially from [any of] their biggest users, the auto industry, or the electronics industry, or aerospace—chair every single, solitary subcommittee, as well as the Standards Committee itself, so that we can define what is going wrong with these robots that we're presently getting.

Now, our standards are not [just] to get better. Our standards are [that equipment be] *absolutely defect-free!* We do not want any defect in the robot *as we receive it*. We expect it to be fully developed. We expect it properly produced, with proper standards of quality, reliability, performance, and all other standards that RIA as a trade association supports for the robotic industries—because we, the auto industry, are the big user, and as I foresee it, we'll continue to be over 50 percent of the market for the next 10 years.

When you talk to any automation equipment manufacturer, not just robot manufacturers, they all claim to burn in their circuit boards and test their equipment before shipment to prevent so-called "infant mortality" in their products. How, then, can you explain the failures Chrysler has experienced?

I think it's because we, as the customer, had not clearly articulated what our needs were to the robot manufacturers, and I don't believe that the robot manufacturers—and I certainly can't speak for them—were properly articulating their needs to their suppliers or subsuppliers. The net result is the failures in the robots we checked, whereby [there were] drive-motor circuit board failures, electrical failures, overloaded drive mechanisms or other mechanical failures, as well as software problems. These items have been categorized by robot, by manufacturer, by detail, and given out to the manufacturers in the RIA for only one reason: to assist them in making their machinery more reliable, more qualified for us [in] the automotive sector—specifically Chrysler Motors—where we're committed to robots' being very importantly involved in our conversion to factories of the future.

Let me give you a specific example of what I'm getting at. In September, 1984 we put 56 electric robots into the respot welding line in Sterling Heights, Chrysler's most progressive world-class assembly plant as we launched the 1985 Chrysler LeBaron GTS and Dodge Lancer. We've had tremendously good results with those robots—once they became reliable.

They were not reliable to begin with?

They were not reliable, but the manufacturer, Cincinnati Milacron, stood well behind their reputation and corrected the problem—but I call that the "pound of cure" instead of the "ounce of prevention" [of] having fully developed the robot and met the requirements of the user. When the user received them, the user had to run the robots through an exercise program and a simulated work program to find that certain gears did not have the proper design and certain components did not have the proper reliability to accomplish a consistent quality run. So... I'm asking each of our robot suppliers the following question: "How do you identify quality or the lack of it in a product or service?" And my best direction to those people is "Does the product consistently do

the job it's supposed to do?" If the product—in this case, a robot—consistently—and the key is *consistently*—does the job it's supposed to do, it's reliable. Usually, robots are in a manufacturing process environment where if they break down, they could shut down the whole operation—Boom!—so they're very critical devices.

Getting back to Sterling Heights: When it launched it had only 102 robots. Now that plant is incorporating a second product to be launched next May—the P-Car, the Plymouth Shadow, and Dodge Sundance, and that plant will then have 222 robots. So we're dramatically committed to robots to assist us in our quality and productivity and flexibility aims in Chrysler

***We, as the customer,
had not clearly articulated
what our needs were
to the robot manufacturers,
and I don't believe that
the robot manufacturers
were articulating
their needs to their
suppliers or subsuppliers.***

Motors. But we need a much better performing robot as a key contributor to our new manufacturing philosophy.

Granted! A good percentage of our readers are either practicing engineers on the factory floor or their supervisors. They recognize that the performance of a robot is very much specific to the program. Robots are even left- and right-handed. Because of factors like hysteresis and backlash in the drivetrain, they may not perform precisely the same way in a right-hand motion as in a left-hand motion. Temperature can affect performance—certainly in terms of repeatability. Just the way a motion is programmed can affect robot performance. Also, since there is an infinite variety of programs a given robot can go through, a unique set of instructions may reveal a hidden defect—a defect the manufacturer just wasn't aware of. Exactly what is the program you're putting these robots through that is revealing these failures? Does the vendor get a very specific program to test it out before it's shipped to Chrysler? Or are they just getting general instructions?

A very good question. The important

thing here is for the user or the customer—in this case, Chrysler—to clearly establish details as to what our requirements are for the environment in which that robot is going to work. Assume, simplistically, we need a robot to apply urethane to glass in a trim line like we would see at Windsor Assembly or Sterling Heights Assembly or the future Chrysler assembly plants. What is the temperature? The load? The cycling? The work envelope? All these different questions will be clearly enunciated to the manufacturer that we choose to produce the robot, and then any other clarifications that are required by that manufacturer will be answered by Chrysler. It is definitely not a general discussion: it's a very concise technical discussion, and every possible thing we can tell a manufacturer we do, to make his/her job more do-able—but then *we expect the results*.

It's interesting [that] in 1980 Chrysler had in its manufacturing processes robots produced by only one manufacturer—Unimation. Today, we have twelve different companies that made the robots in our manufacturing operations. We are constantly searching the world for the best robotic producers, whether they're in Europe, Asia, or North America. The technologies are changing, and we will continue to see who can best service our needs. [See Table 1.]

Would you please clarify the difference between the 50-hour test and the 20-hour test?

Basically, the 50-hour test is something like a breaking-in, a general review of the exercising of the robot, not necessarily at any one given speed or load or motion [and] not for any specific environment. It's somewhat generic. The 20-hour reliability test, however, is very specific to the application, and closely simulates the working load and conditions under which the robot will actually operate.

Bob Piccirilli and myself and others are actually spending days trying to communicate our needs to the various manufacturers and the trade association, because we represent a massive market segment and we simply do not want to have a "get better" mentality, we want an absolutely defect-free mentality. We're getting an outstanding understanding from the different chief executives and the chief operating officers of the 12 robot suppliers to Chrysler. They totally understand

there's a problem. They totally respect there's been a communications gap, and they want their industry to grow, their own company to grow, and they want to continue to be on the bid list for Chrysler.

The generation of robots we put into Windsor in 1983 were good robots, but they are not nearly as good as those we put into Sterling Heights in 1984, which, in turn, are not nearly as good as the ones we're putting into Dodge City, which will launch very quickly. The ones there will not meet the standards of what we want in the 1986 calendar year when we launch St. Louis, Missouri, where, by the way, we're going to go from 74 robots in the two assembly plants today to 320 robots by September. So, just a few months from now, St. Louis will have almost 400 percent more robots than it has today. While we've concentrated on the vehicle assembly division, we're now starting to massively multiply applications in our machining and casting operations in our powertrain division plants. We're also starting to use robots in a much, much greater way in our stamping and metalforming plants. [See Table 2.]

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

1	11	21
Excellent	Good	Fair

Continued from page 6

- quality measurements
- error cause removal
- repeating the process—QIP is a never-ending process demanding constant assessment and adjustment.

Chrysler's long-range plan calls for spending \$12.5 billion in the next five years. Manufacturing is expected to get 41 percent or \$5 billion plus. Out of this \$5 billion, suppliers of facilities, tooling, and equipment can expect to get \$4 billion. Robot builders are expected to get a significant portion of that \$5 billion.

In addition to introducing seven new models over the next 36 months, Chrysler has three specific goals for the next five years:

- Defective quality citations/100 vehicles must decrease by 56 percent.
- Costs must decrease by 30 percent, or over \$2000/vehicle.
- The time to bring a new vehicle to market has to be cut 25 percent—from

Manufacturer	1980	1985
ASEA	0	38
Cincinnati Milacron	0	243
Devlbiss	0	4
General Electric	0	18
GMF	0	12
Graco Robotics	0	48
Kuka	0	14
Motoman	0	7
Prab	0	88
Robotics Inc	0	16
Unimation	197	386
Other	0	26
TOTAL	197	900

	Assembly Plants	Stamping Plants	Powertrain Plants	Other	Total
Spot Welding	670	—	—	—	670
Material Handling	6	39	14	—	59
Spray Painting	56	—	—	—	56
Training & Misc. Other	9	—	—	21	30
Adhesive/Sealant Application	12	15	—	—	27
SubAssemblies	26	—	—	—	26
Assembly	—	—	15	—	15
Arc Welding	6	1	—	—	7
Glass Preparation	5	—	—	—	5
Machine Loading	—	4	1	—	5
TOTALS =	790	59	30	21	900
Electric Drive =	404	41	26	N/A	
Hydraulic Drive =	386	18	4	N/A	

five years to less than four years.

Chrysler's expansion plans call for investing close to \$0.5 billion in the Dodge City complex in Warren, Michigan which will produce large or small pickups in any ratio between 0 percent and 100 percent. At startup, March, 1985 156 robots and 835 computers were installed—representing a buildup from only one robot and 53 computers in only 12 weeks. Clearly, unproven or unreliable systems at any startup spell disaster. Future plans call for 2350 robots in Chrysler by 1990—a 161 percent increase over 5 years. [See Table 1.]

A "bare bones" robot costs about

\$90,000. On average, the total investment, including plant facilities, tooling, and installation, is generally some two-to-three times that of the robot itself, or about \$300,000. The 1450 robots we plan to install over the next five years will cost approximately \$500 million. The \$5 billion manufacturing capital investment must create a vehicle that is cost-competitive and that takes less time from the drawing board to the dealer showroom. Unless quality is built into these manufacturing systems, quality goals and production plans simply cannot be implemented. We've taken steps to ensure that equip-

Year	1985	1986	1987	1988	1989	1990
Robots	900	1140	1440	1960	2190	2350

The investment is expected to total \$500 million.

ment and systems are consistently reliable—as received by our plants. All robots received by any plant or systems integrator on our behalf must pass a 50-hour quality test wherein the equipment is exercised through its design parameters for 50 hours. An actual tool or simulated load is attached to the wrist and the arm is exercised through all axes of motion.

Results of the 50-hour test shocked us. Of the 200 or so robots tested under the program, about 50 broke down before we even attempted the application. No robot, American, Japanese, or European passed. The top five problems were:

- Drive motor circuit board failures—the boards had to be redesigned.
- Defective drive mechanisms had to be replaced.
- Incorrect fuses had to be replaced.
- Software problems. On powerup, the robot would occasionally move unexpectedly. The software had to be debugged.
- Overloaded drive mechanisms. Arms had to be stiffened and weld guns redesigned.

Had these systems and robots entered the assembly plants without the 50-hour test, quality and production would have

been badly hurt, and launch programs could not have been met on time.

In addition to our 50-hour test program, all equipment has to pass a 20-hour reliability test before we allow it to be shipped to our plants. In this test (at the equipment build source), the robot must cycle automatically—without any break whatsoever—for 20 continuous hours. The 20 hours approximates a full day's actual service. Any breakdown or failure requires the clock to be reset to "time zero" and the test restarted—until a successful run has been completed. All process equipment, not just robots, must pass this test. A key purpose is to establish equipment reliability independently from product quality in an actual production environment.

Again, the results of our 20-hour reliability test program have dramatically

FLEXIBLE ASSEMBLY SYSTEMS

MODULES FOR ASSEMBLY

VSI AUTOMATION ASSEMBLY can solve your assembly system needs with standard modular components. Equipment can be utilized for individual workstations or incorporated into systems. Call us for application assistance to maximize your assembly system cost effectiveness.

AUTOMATED SCREWDRIVERS: Single or multi-spindle systems are available to reduce assembly time and improve product quality. Blowfeed or trackfeed units with centerboard hopper feeders and a multitude of electric and air motor drives are standard. Options include quality control checks such as: height, screw presence and fastening checks.

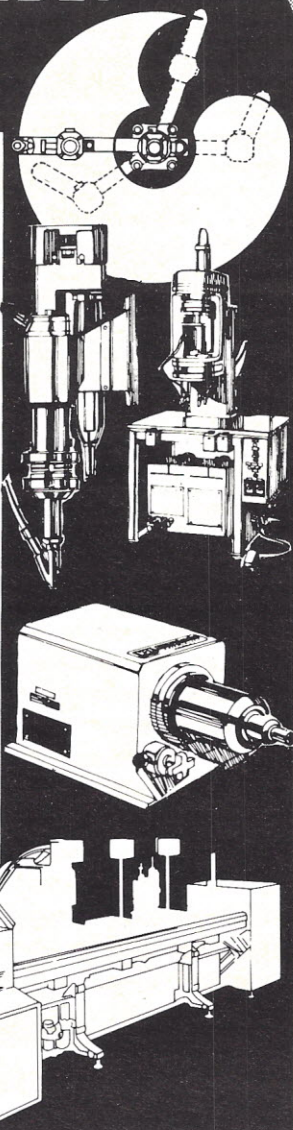
EOA TOOLING: All types for multi-axis and SCARA robots and x-y-z tables are available. Automated screw-driving and pin insertion units are standard.

SCARA ROBOTS: Charley™ SCARA assembly robots are available in 3 size ranges with various controller options. Universal adaptor allows for any type tooling. Also available are dedicated screwdriver SCARA robots, x-y-z tables and specialized tray-handling equipment.

NON-SYNCHRONOUS TRANSFERS: (Flexible in-line and carousel) are available to adapt to product assembly or floor space requirements. Pallet sizes vary from 150 x 200mm to 600 x 800mm with $\pm .002$ inch location repeatability.

Spinomatic ORBITAL FASTENING

UNITS: Provide high-accuracy noiseless riveting, crimping and swaging through controlled pressure and motion. These precision systems (for metal and plastic applications) with capacities from .010" to 1.88" diameter are available in standard tablemount or pedestal styles and can be incorporated into automatic systems. Options include multi-spindle and multi-point forming heads. Call for application assistance.



VSI AUTOMATION ASSEMBLY

165 Park Street, Troy, MI 48063
(313) 588-1255 — TWX (810) 232-9897

See us at ROBOTS 10, Booth #4049

Results of the 50-hour test shocked us. Of the 200 or so robots tested under the program, about 50 broke down before we even attempted the application. No robot, American, Japanese, or European passed.

proven our need to place quality and reliability at a higher level in our plans. For systems intended for just two assembly plants, we experienced 393 breakdowns on 48 systems—causing up to 10 days' quality nonconformance just to secure a 20-hour continuous run. The true impact is that it kept 393 *major breakdowns* out of our Dodge City and Sterling Heights Assembly plants—avoiding the loss of as much as \$10 million per day per plant!

Finally, a look at the future. In our three most modern assembly plants, there are only two or three robots in what we call the "Trim, Chassis, and Final" (TC&F) areas. We believe this is where robotic growth opportunities lie, and we're now firming up plans for a cooperative process development program whereby the TC&F areas can be at least 80 percent automated. The robots will have vision and intelligence plus self-diagnosis and recovery. Future technology in Chrysler plants will depend on what we can accomplish in this development program.

玻璃纤维光学
激光

FIBER OPTICS / LASERS

自动化制造

AUTOMATED MANUFACTURING

微型电子学

半导体

MICROELECTRONICS / SEMICONDUCTORS

China's international exhibition and conference
on advanced manufacturing systems,
fiber optics/lasers and
microelectronics/semiconductor production

EXPO HITECH SHANGHAI 86

Shanghai Exhibition Center
October 30-November 6, 1986

JOIN THE RIGHT MARKETING EVENT IN CHINA

- Unprecedented official support throughout China.
- First time market report and shopping list available to identify your marketing opportunities in China.
- The key enduser groups throughout China will be delivered.
- If you are in the Automated Manufacturing, Fiber Optics/Laser, Microelectronics/Semiconductor Production industries ...

Can you afford not to exhibit in EXPO HITECH 86!

ORGANIZED BY:



E.J. Krause & Associates, Inc.

P.O. Box 70356

Washington, DC 20088 U.S.A.

tel. (301) 986-7800

tlx. 4944944 EJK EXPO

Contact: William R. Burris

Yes, I'm interested in exhibiting in EXPO HITECH 86.
Please send a copy of the Prospectus and Market Survey to:

Company _____

Address _____

Contact _____

Title _____

Telephone _____ Telex _____

Justifying High-Tech Manufacturing Solutions Through JIT-TQC-CIM

Dr. Ani D. Chitale

Automation Management Services, Inc.
3580 Mark Drive
Broadview Heights, OH 44147

Manufacturers worldwide are fighting to increase productivity and win in the international marketplace. Over the last 10 to 15 years, several Japanese and Korean manufacturers have established themselves in industries traditionally dominated by U.S. manufacturers. The U.S. has lost leadership in industries that manufacture products such as ships, clothing, cameras, cars, video and audio recorders, televisions, and high-volume semiconductors. Other fields such as computers, telecommunications, satellites, software, chemicals, and aerospace are not yet lost.

Experts from several large accounting and management consulting firms suggest that future manufacturing will be led by Japan and other Asian countries and that the U.S. economy will be led by the service industry. But others who understand manufacturing economics believe that this

could only be a self-fulfilling prophecy. The pressures for short-term returns on investment or the acceptance of a distributorship sort of business strategy has pushed several U.S. firms to either give up manufacturing some product lines or move overseas in the hope of benefiting from lower labor costs and subsidies. The effect of this strategy, however, is becoming more and more clear. A portion of every manufacturing dollar spent outside the firm nurtures the vendor, creates his manufacturing assets and supports his fixed costs. This vendor could be your future competitor. In many high-tech businesses, loss of manufacturing strength could also mean eventual loss of R&D product technology leadership.

Can U.S. high-tech businesses remain viable as leading developers and product inventors, reaping high-margin benefits in

the first few years of new product cycles and then leaving manufacturing to international competition? The answer seems to be a definite "No," as many firms dealing with semiconductors, computers, and other products are coming to realize. Many U.S. manufacturers are fighting back and winning. How to successfully apply manufacturing know-how in high-tech businesses to obtain long-term leverage is our subject.

AUTOMATE, EMIGRATE, OR EVAPORATE—THE CATCH 22

This manufacturing philosophy reached North America a few years ago, and it seemed that at every social function some executive would declare his firm's automation or emigration strategy. Still, many high-tech firms have found it difficult to implement this philosophy. Some even realized the pitfalls. Four major factors worked against their survival intentions: the nature of the high-tech product-process cycles; the use of conventional, labor-based accounting; the socioeconomic differences between the U.S. and the Far East industries; and, the automation of shop floor activities such as fabrication and assembly, which could not in itself vitalize the manufacturing arm of the company. Let us take a closer look at these factors.

The High-Tech Product-Process Cycle. The nature of transitioning R&D product technology through initial prototype, pilot,

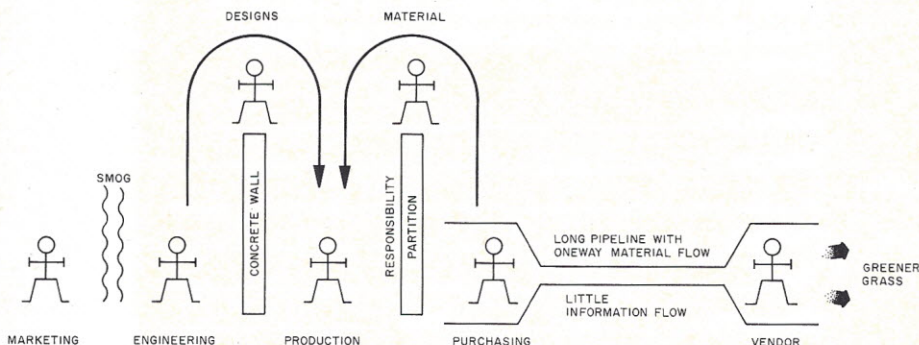


Figure 1. The working relationship between design and production engineers can be represented as a volleyball game over a concrete wall.

and on to full-scale manufacturing is such that the effectiveness of the manufacturing system and the ability to introduce mature designs are closely interdependent. We will use the term "manufacturing" to include all system functions such as product design, process design, production, purchasing, cost accounting, and other decision support elements.

The characteristics of the cycle are

- High rate of design changes
- New processes
- Technological uncertainties
- Short product life cycles, and short time frames for designing, scale-up, manufacturing, and phase-out
- High-risk decisions

In the initial stages, the R&D function has cost and time pressures for product introduction, while production most often resigns its fate to living in the imperfect world of Engineering Change Notices. In many cases, it is analogous to a volleyball game over a concrete wall (Figure 1). In other words, manufacturing and design functions require such close interfacing in the initial stages that the project is difficult to pull off successfully if initial production is a vendor's responsibility. Further, if production is moved overseas under these circumstances, the chargeback for engineering changes and initial field problems falls into the production bucket as overhead, like most common accounting practices.

Conventional Accounting Practices. The movement of production to overseas vendors also means a decrease in capacity use and excess of overhead in the U.S. plant. While top management reacts favorably to the immediate cost-reduction benefits from moving overseas, plant closing and reduction of overhead are many times left within the scope of production operations. The end result is an increase in "burden rate" for every overseas move, thereby creating justification for the next overseas move, leading eventually to a loss of manufacturing strength.

Furthermore, as the direct labor percentage reduces, the overhead burden rate based on direct labor becomes artificially higher. It is unfortunate that while our accounting professionals are busy implementing accepted accounting principles for external business financial reporting, little attention is paid to the need for accurate cost accounting as a decision support tool.

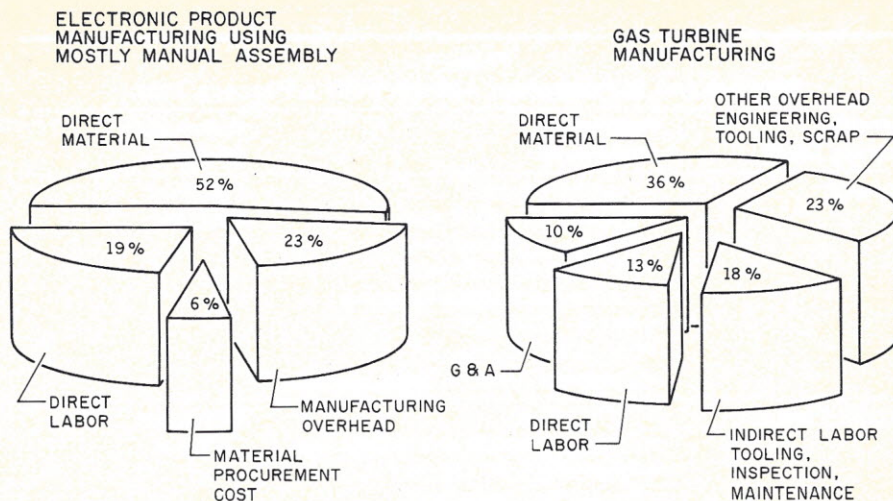


Figure 2. A breakdown of typical manufacturing cost elements demonstrates that direct labor is only a small factor—as little as 3 percent in some instances.

The Power of the Socio-Economic Weapon. Except for theoretically vertically integrated businesses, most manufacturers depend on a significant portion of incoming raw materials to consist of value-added subcomponents ready for assembly. Some even benefit from the high-margin systems integration activities. But the supplier-buyer relationship's viability is based on the premise that the vendor is not a potential competitor. U.S. businesses, accustomed to the economic freedom and business practices within the continent, find it difficult to foresee or to accept the moves of their international colleagues. For example, even a cursory look at the management structure of 10 major Japanese companies and the 3 major Japanese national banks reveals the financial integration of the industries. Add to this the lifelong relationship between a Japanese company and its management and other workers, and the patience of the investors.

Comparing business strategies on a one-to-one basis is meaningless in this situation. While labor costs are on the increase in Japan (although the rate of productivity increase still exceeds that of the U.S.), other low-labor-cost nations such as Korea and China are bound to move into manufacturing. Thus, U.S. manufacturers can always find vendors willing to outbid any quote by their in-house operations, as long as the volumes are large enough. The eventual loss of manufacturing capabilities and proprietary product technology is the only trade-off against short-term economic pressures.

An added complexity in recent times has

been the practice of differentiated raw materials pricing by many overseas suppliers. People with experience in operating U.S. Asian plants are aware of 30 to 40 percent average cost differences between semiconductors, other electronic components, wire harnesses, moldings, and so forth supplied to the local plants vs. those supplied to the U.S. plants on shore.

Shotgun Automation. The early 1980s rush toward robotics and flexible manufacturing systems (FMSs) as a cure for manufacturing ills is now settling down to more appropriate levels. In those years, automation of shop floor tasks such as fabrication, assembly, inspection, and material handling was seen as a solution for reducing or virtually eliminating shop floor labor. Many automated storage and retrieval systems erected in those days are now coming down. The shotgunning of shop floor labor through automation did not always produce the desired improvements in manufacturing productivity. The reason is simple enough. Figure 2 shows typical manufacturing cost elements in two high-tech industries. Direct labor is only a small fraction of the total cost. In some computer manufacturing operations, direct labor can be as much as 3 percent of total cost, while materials are almost 70 percent. With the improved technologies and increased operations management complexities of the last two decades, overhead costs as a percentage of value addition have steadily increased, while direct labor percentages have declined.

Table 1
Support and Management Activities for a Process Task

Manual Activity Level	Functions Performed	Automation Device
Operator	<ul style="list-style-type: none"> • Equipment Setup • Operation Stop/Start and Processing Controls • Part Test/Inspect/Record • Job/Operation Status Reporting • Material Movement • Equipment Maintenance • Equipment Condition Status Reporting 	Equipment Controller
Operator/Foreman	<ul style="list-style-type: none"> • Lot Stop/Start • Process Balancing and Material Flow • Processing Specifications Storage and Assignment • Part Test/Inspect/Record • Job Status Reporting • Material Movement 	Workstation Controller
Foreman/Supervisor	<ul style="list-style-type: none"> • Factory Data Consolidation/Preprocessing • Cell Job Dispatch • Process Balancing and Material Flow Control • Processing Specifications Pass-through • Cell Communications Handling 	Cell Controller
Plant Manager	<ul style="list-style-type: none"> • Detailed, Short-interval Work Order Scheduling • Plantwide Job Dispatch • WIP Tracking and Management • Factory Data Collection and Reporting • Processing Specifications Pass-through • Test Specifications Pass-through 	Production Control Distributed Processor

Recent studies by the American Electronics Association suggest that in the electronics industry simple manufacturing systems such as job shops for government projects have overheads of approximately 60 percent of value added, and the ratio increases to almost 70 percent for the microcomputer industry, where high volumes and automated processes lead to increasingly complex manufacturing operations.

The focus of direct-labor-cost reductions through process-equipment-based automation (mechanization) generally also requires a greater initial investment per dollar saved than the application of systemization solutions. Also missed have been the significant opportunities for material cost reduction through appropriate product design solutions and purchasing techniques. A case in point is the use of standard equivalent chip packages by offshore vendors replacing "hard-to-procure" components specified in a U.S. logic board design. The cost savings op-

portunities through a reduction of indirect activities can be seen in Table 1, which illustrates the support and management activities typically performed for a single-shop floor process task.

JIT-TQC-CIM: A UNIFIED APPROACH FOR MANUFACTURING SOLUTIONS

Global competition has seriously challenged our understanding and implementation of production, operations, process technology, inventory control, and quality control. World-class manufacturers are being forced to perfect production, process, and quality control techniques in the search for higher quality, timely delivery, and lower product cost. Just in time (JIT) and total quality control (TQC) are two powerful tools for achieving these objectives. Another is computer integrated manufacturing (CIM). JIT-TQC can prepare the ground and provide an approach for implementing viable automation solutions.

JIT-TQC Can Lead The Way. JIT has received a number of labels since it was discovered in the U.S., applied successfully by the Japanese, and rediscovered by U.S. manufacturers. It has been called a pull-type scheduling system (*Kanban* in Japanese), an inventory reduction program, a setup time reduction program, the road to automation, and so on.

The accompanying representations do not define JIT but only list some of its features. JIT is a philosophy and a technique of continually reducing waste in all aspects of manufacturing (Chart 1).

The practice improves the health of the manufacturing operations. It affects design, plant layout, processes, quality management, purchasing, vendors, employee relations, and financial operations. It reduces finished goods, incoming and work-in-process inventory, and leads to small batches, quick setups, and reduced throughput time.

TQC is necessary for implementing JIT and is an integral part of the JIT philosophy. A major pitfall for firms implementing JIT is a lack of sufficient focus on TQC. Quality and process problems are exposed by JIT techniques, while TQC solves them. Reducing incoming inventory requires integration with vendors' process quality and delivery schedules. Reduced work in process, small batches, quick setups, and reduced throughput time all require preventive quality measures and "no surprises" during operations. This is possible only with high equipment uptime, process control, material quality, and a smooth transition of design-to-production.

Results for companies successful in implementing JIT-TQC are impressive. A U.S. computer manufacturer recently saw these benefits:

- 50 percent reduction in manufacturing floor space
- 85 percent reduction in product manufacturing throughput time
- 90 percent reduction in machine setup time
- 80 percent reduction in work-in-process materials
- 200 percent improvement in process quality
- 83 percent reduction in scrap and rework

Generally, the Engineering Change Notices that flow between engineering and production are an indirect reverse measure

New and Recent Titles in Robotics

Transducers for Microprocessor Systems

J.C. Cluley

Explains the use and application of transducers and sensors in the sequence of signal transformations, which starts with measuring events or conditions in the outside world and ends with the loading of some numerical representation of the event or condition into a register within the microprocessor. Also surveys output transducers which control devices and variables that are under the microprocessor's command.

1985/107 pp./hardcover \$22.50
ISBN 0-387-91268-1

Co-published with Macmillan Publishers Ltd.

Toward the Factory of the Future

Proceedings of the 8th International Conference on Production Research and 5th Working Conference of the Fraunhofer-Institute for Industrial Engineering (FHG-IAO) at University of Stuttgart, August 20-22, 1985

Edited by H.-J. Bullinger and H.-J. Warnecke

1985/960 pp./hardcover \$77.00
ISBN 0-387-15762-X

Co-published with IPA/IAO

CAM: Developments in Computer-Integrated Manufacturing

Edited by D. Kochan

Authors from seven countries present a comprehensive overview of the latest developments in the field.

Contents: Introduction. Computer-Aided Manufacturing (CAM). Stages of Development in Flexible Manufacturing. Methods of Decision-Making for Investments. Geometric Modeling. Integration of CAD/CAM. Techniques of Software Design for CAD/CAM. Artificial Intelligence. Development of CAD/CAM to CIM. Appendices I and II. References.

1986/289 pp./157 illus./hardcover \$57.00
ISBN 0-387-15165-6

IFIP (International Federation of Information Processing) State-of-the-Art Reports

Control of Electrical Drives

W. Leonhard

Supplies a unified treatment of the complete electrical drive system, including the mechanical load, the electrical machine, the power converter, and the control equipment. While conventional DC drives are fully discussed, special emphasis is put on AC drives which are becoming more common. New

topics such as microelectronic controls make this a state-of-the-art account of the field.

1985/346 pp./270 illus./hardcover \$49.00
ISBN 0-387-13650-9

Electric Energy Systems and Engineering

Integrated Manufacture Ingersoll Engineers

Edited by J. Mortimer

Draws upon the corporate experience of Ingersoll Engineer's consulting staff and that of sixteen sample companies in the USA, UK, France, and Germany. It explains the meaning of integrated manufacture, the relation of CIM to existing business functions, and ways to make CIM work.

1985/188 pp./softcover \$89.00
ISBN 0-387-15612-7

Co-published with IFS (Publications), Ltd., U.K.

Robot Grippers

Edited by D.T. Pham and W.B. Heginbotham

Ranging from practical applications to concepts for research and development, this book explores grippers for robots and automata. It is divided into five sections: basics of grippers and gripping, design of grippers for irregularly shaped, flexible, or fragile objects, design of jaws or fingers, design of devices for interchanging grippers, and design of advanced grippers with multiple degrees of freedom.

1986/approx. 360 pp./hardcover \$59.00
ISBN 0-387-16004-3

International Trends in Manufacturing Technology. Co-published with IFS (Publications), Ltd., U.K.

Robot Sensors

Edited by A. Pugh

This selection of papers spans the fundamental experiments conducted in robot sensing over the past decade as well as the most recent developments.

Vol. 1: Vision

Includes an overview of imaging sensors plus highlights of recent work by specialists. Papers also treat fiber-optic sensors, laser-based sensors, and scene illumination.

1985/approx. 300 pp./hardcover \$49.50
ISBN 0-387-16125-2

Vol. 2: Tactile and Non-Vision

More extensive than the first volume, this part surveys this more developed area of robotics applications and covers passive and active force sensors, tactile array sensors, transduction, and acoustic/ultrasonic sensors.

1986/approx. 350 pp./hardcover \$54.00
ISBN 0-387-16126-0

International Trends in Manufacturing Technology. Co-published with IFS (Publications), Ltd., U.K.

Robot Modelling: Control and Applications with Software

P.G. Ránczy and C.Y. Ho

This step-by-step survey of the theory and application of industrial robots offers case studies, numerical examples, and sample robot programs. It develops a general mathematical model applicable to any robot, and provides in-depth coverage of the programming, tooling, design, and testing of robot systems.

1985/361 pp./150 illus./hardcover \$45.00
ISBN 0-387-15373-X

Co-published with IFS (Publications), Ltd., U.K.

Robotic Assembly

Edited by K. Rathmill

Contains twenty-seven papers by experts in the field of robotic assembly. The book is divided into six sections: assembly robots, robot assembly systems and applications, product design, programming systems, sensory systems, and the social and economic impact of automation.

1985/349 pp./100 illus./hardcover \$39.50
ISBN 0-387-15483-3

International Trends in Manufacturing Technology. Co-published with IFS (Publications), Ltd., U.K.

Flexible Manufacturing Systems

Edited by H.-J. Warnecke and R. Steinhilper

Explores the present international state-of-the-art and future development of FMS, drawing upon the experiences of FMS researchers, consultants, planners, and users. Answers such questions as for which purposes are FMS suitable, how do you plan a FMS, which designs promise success, and what economics benefits can be expected.

1986/312 pp./100 illus./hardcover \$54.00
ISBN 0-387-15888-X

International Trends in Manufacturing Technology

To Order: Please visit your local academic/technical bookstore, or send payment, including \$1.50 for postage (NY and NJ residents also add sales tax), to the address below. Personal checks, money orders, and VISA, MC, and AmEx credit card numbers (include expiration date) are acceptable forms of prepayment.

Springer-Verlag New York, Inc.
Attn: Ken Quinn, Dept. 360
175 Fifth Avenue
New York, NY 10010



Springer-Verlag
New York Berlin Heidelberg
Vienna Tokyo

Chart 1
The Interlinking Impacts of JIT-TQC Implementation

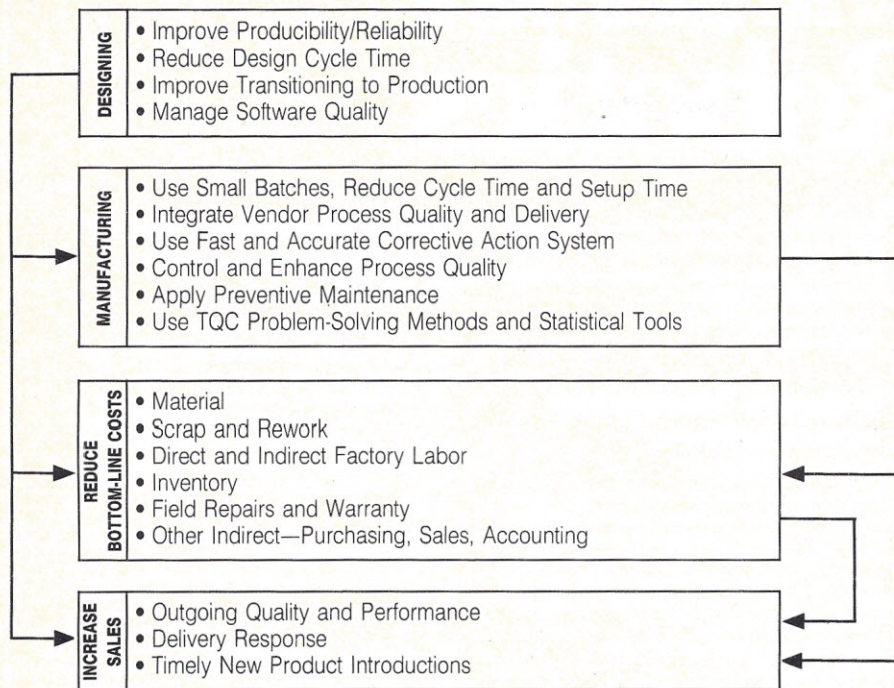
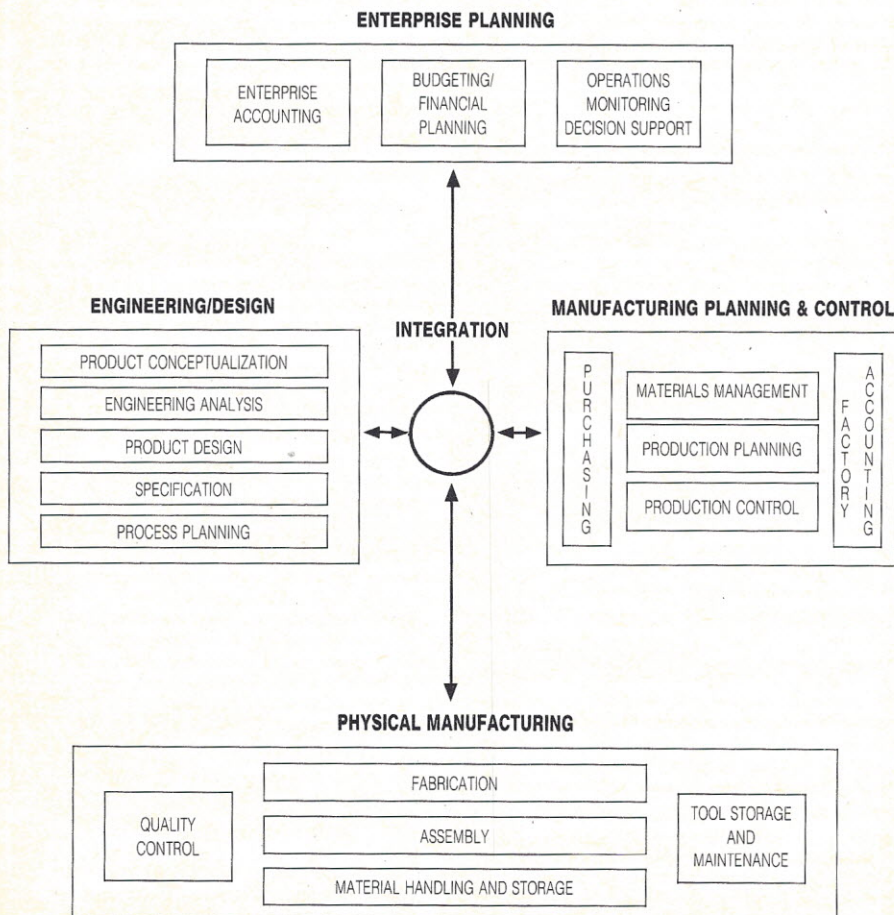


Chart 2
Functional Areas Covered by CIM



of the maturity of the design as it is released for production. In some high-tech businesses, ECNs continue at a high rate almost throughout the design life. The costs of changes, defectives, and scrap remain hidden in the production budget, while management finds it difficult to identify the root cause of high production costs and schedule overruns. JIT-TQC also provides long-term benefits in this situation. The improved designs reduce material, assembly, test, and inspection costs. Improved management of the design-to-production transition reduces total project time and cost. Chart 1 illustrates the interlinking effects of JIT-TQC implementation.

JIT and TQC are not complex concepts, nor do they involve complex techniques, but implementing them is difficult because new ways of thinking are involved. With experienced help, successful JIT-TQC pilot projects can be started in 30-90 days, although it may take several months, or years, before JIT-TQC becomes a modus operandi. Are the results worthwhile? For an increasing number of companies, learning about and implementing these breakthrough manufacturing methods is quickly becoming a matter of survival.

IMPLEMENTING CIM IN HIGH-TECH COMPANIES

Computer integrated manufacturing involves computer aided functions in all activity areas within a manufacturing system (not just the factory) and the integration of functions (where necessary) through electronic communications and data sharing. CAM (computer aided manufacturing), robotics, and robotic controls are subsets of CIM on the shop floor. CAD and CAPP (computer aided process planning) are subsets as applied to engineering/design activities. Chart 2 shows the functional areas covered by CIM.

Computers increase the flexibility, speed, reliability, and repeatability of tasks and allow their integration with other related tasks. This capability is used to perform both shop floor and other indirect activities. Except in the case of a totally automated system, CIM involves a mixed deployment of human, machine, and computer capabilities. Dedicated automation systems such as those for conventional assembly lines are appropriate for high product volumes, product designs with in-

frequent changes, and a market with delivery and price pressures. Flexible manufacturing systems that involve significant shop floor automation of fabrication, assembly, and material handling, on the other hand, are appropriate when product designs must change frequently. These systems are applicable to relatively higher volume, more stable stages of some high-tech businesses.

Major benefits come from indirect activity areas such as factory overhead and R&D. But FMSs have two major limitations: tooling and hardware remain relatively inflexible, and fixed costs increase significantly, thereby increasing risk in changing markets. For high-tech businesses that deal with relatively lower volumes and that leverage frequently improved designs/technologies, a flexible human system approach could be more appropriate.

Flexible human systems can lead to more cost-effective manufacturing solutions because of their attack on all indirect and support activities and information flows beyond the direct labor tasks. They automate shop floor tasks only to an extent that will reduce or eliminate subse-

quent support tasks such as those for planning, scheduling, and quality control.

JIT-TQC As First Steps Toward CIM.

One of the major pitfalls in implementing CIM is the automation of functions without changing the conventional methods of operation. Such direct automation efforts result in automated wire-guided material handling systems, high-rise storage areas, and complex inventory planning and control systems. None of these would be necessary if inventory were minimized and a JIT pull system established. While the ultimate JIT, *Kanban* ticketing, may not be applicable in all manufacturing situations, the simplification of functions and elimination of unnecessary tasks before automating them is the key. JIT-TQC allows us to achieve the inherent limit of current process capability by improving all operations and productivity. Automation with continuing JIT-TQC then improves the limit of process capability and productivity.

In high-tech industries, design and manufacturing engineering are key functions that affect manufacturing cost, quality, and delivery. The producibility, testability, and

reliability of the design can dictate material cost, direct assembly, and test labor, all indirect labor such as scheduling, planning, supervision, quality assurance, scrap and rework, process equipment, fixturing expenditures, and even plant floor space. Improving designs through the application of "design for assembly" rules, producibility guidelines, and improving the design-to-production transition can offer significant savings in material, burden, and direct labor and can improve quality as well. Computer aided design and process planning allows us to effectively implement the JIT-TQC approach. This is a powerful approach for CIM, which is the technological tool for future manufacturing systems solutions.

Dr. Chitaley is President of Automation Management Services, Inc.

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

2	12	22
Excellent	Good	Fair

"Your search for a 50,000 count* encoder is over . . . and still under \$500.00"

Introducing the BEI M5 Interpolate Encoder.

The BEI M5 encoder provides the ability to subdivide a cycle into smaller divisions, improving system resolutions up to 50,000 counts per turn while maintaining a ± 1 count accuracy.

This increase in resolution is achieved in a standard 2.5" dia. industrial package without sacrifice to mechanical integrity or internal electrical signal strength.

The M5 is ideal for position readouts and position servos. Its features include the same options (over 17 million configurations) found in the standard BEI encoder line.

* 12,500 cycles per revolution allows quadrature detection of 50,000 counts per turn. (alternate resolutions available).

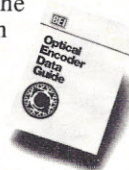


Renowned for their unmatched quality and reliability, BEI's products are backed by the finest technical and service support imaginable. And without compromising quality, BEI guarantees a 4-week delivery, even faster with optional expedited delivery!

So if you're searching for the right encoder for the right job and you need it now, search no longer. Call and talk to our experts.



Find out why BEI is recognized as "The Encoder Company". And be sure to ask for your copy of the Optical Encoder Design Guide. It's free.



BEI BEI Motion Systems Company
Industrial Encoder Division

7230 Hollister Ave.
Goleta, CA 93117
(805) 968-0782
Telex: 888069 (BEIIED)

Multiple-Arm Control and Assembly Operation

Gordon Mayer and Elaine Ide Wood

Adept Technology, Inc.
1212 Bordeaux Drive
Sunnyvale, CA 94089

Robots and vision technology have advanced to a point where the ideal of flexible assembly is a reality. A demonstration flexible assembly cell designed to assemble automotive oil pumps has been built to incorporate the following capabilities:

- Sensory-driven assembly
- Dual robot communication and coordination of overlapping work envelopes
- Real-time process verification
- Real-time response to errors
- Real-time assignment of task priority
- Cell control integrated into multi-tasking robot controller (no separate cell controller)
- Simple parts feeding (no "tooled" parts presentation)
- Complete assembly within one cell (the opposite of sequential assembly lines)

In this article, we will look at the oil pump and the assembly layout, part presentation, the sensors employed, assembly sequence, and, finally, cell control and programming, highlighting how priorities were determined in real time to guide the robots to the proper assembly sequence.

THE OIL PUMP

The oil pump (Photo 1) consists of eight parts:

1. Housing (1)
2. Mating gear (1)
3. Shafted gear (1)
4. Cover (1)
5. Bolts (4)

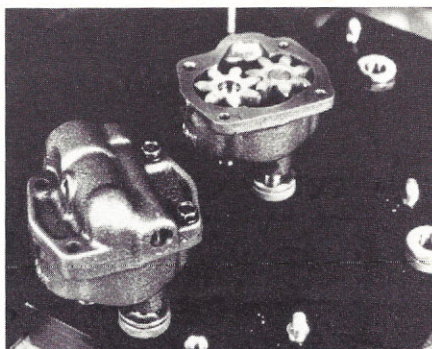


Photo 1. The oil pump to be assembled consists of eight parts.

An assembly begins with the housing. The mating gear is inserted over a shaft in the housing, followed by the insertion of the shafted gear. The cover is then placed on top and secured with the four bolts.

THE CELL LAYOUT

Based on the initial cycle time analysis, the cell was designed with three assembly stations accessible to both robots. The entire system (Photo 2 and Figure 1) consists of:

1. Two AdeptOne™ robots and controllers; a five-axis AdeptOne was the transfer robot and a four-axis AdeptOne was the assembly robot
2. Moving-line AdeptVision™

3. Arm-mounted area AdeptVision
4. Z-axis force sensing
5. Arm-mounted screwdriver
6. Instrumented grippers
7. Three instrumented assembly stations
8. Gear presentation tray
9. Bolt presentation tray
10. Simple 12-in. wide belt conveyor
11. Finished parts pallet

PART PRESENTATION

The parts feeders were designed to demonstrate two capabilities. First, the feeders are "simple" in that they are not tooled for a specific part. Therefore, the same feeders can present different parts and the cell can be truly flexible, capable of assembling a variety of pump products. Second, the feeders present housings, covers, and gears in random orientations and positions to demonstrate that it is no longer necessary to precisely position parts in order for the robot to find them.

The belt conveyor feeds pump housings and covers to the transfer robot. The housings and covers travel on the belt at random intervals and in random positions and orientations. The moving-line vision system locates the parts by constantly monitoring the conveyor and identifying their location on the belt, and communicates part locations to the transfer robot.

The shaft gears and mating gears are

Photo 2. The workcell consists of two robots with overlapping work envelopes, vision and other sensors, a simple conveyor belt, and the robot controllers.

loosely presented on a simple tray in the assembly robot work envelope. Area vision locates their exact positions and identifies grip points. The tray of gears is too large to be viewed with a stationary camera, so the camera is mounted on the robot arm where the robot can control camera position as needed. The bolts are also presented on a simple tray within the work envelope. The position of the bolts is known accurately enough that no vision capability is needed to locate them.

SENSORS

Several tasks require sensory interaction in order to reliably perform the assembly. Some of the most important sensory tasks include detecting part acquisition and placement errors and recovering appropriately, inserting gears reliably, and automatically fastening the four bolts.

Real-time errors must always be anticipated when acquiring and placing parts. In this cell, errors can occur when taking parts from the belt, gear tray, or bolt tray. Placement errors can include improper placement onto the assembly station, improper setup of the station, and improper driving of the bolts.

To detect errors when acquiring housings and covers, simple contact switches in the transfer robot gripper indicate whether the part is in the gripper. Contact switches in the assembly stations detect that the housings are placed correctly. A pneumatic cylinder in each assembly station actuates a locating pin on which the housing is seated. If this pin does not extend or retract at the appropriate times, the assembly can fail. Therefore, magnetic presence sensors in the assembly station verify that the pin is in its proper position.

To reliably insert the gears, a Z-axis force sensor on the third axis of the assembly robot detects jamming and guides the robot to apply corrective moves. For example, when placing the second gear into the housing, the robot spins the gear about its vertical axis until the force sen-

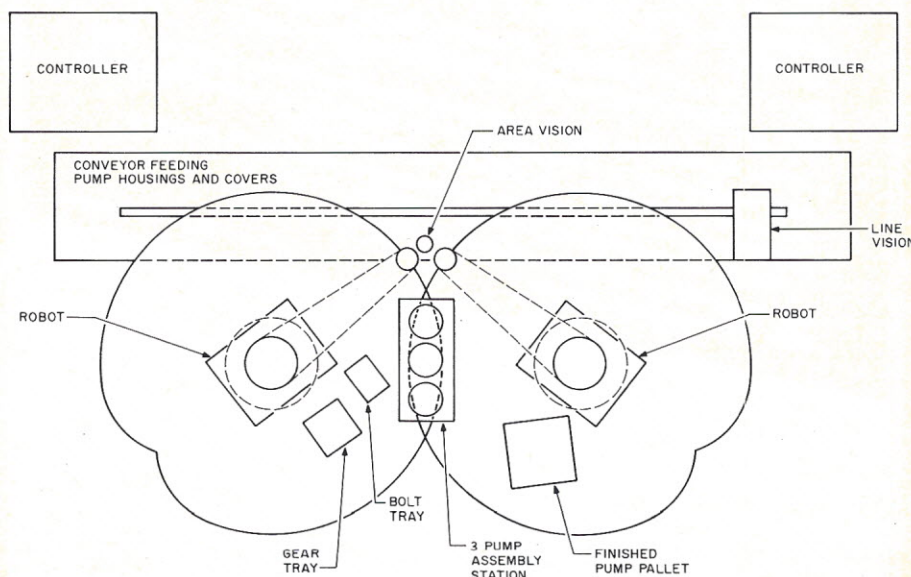
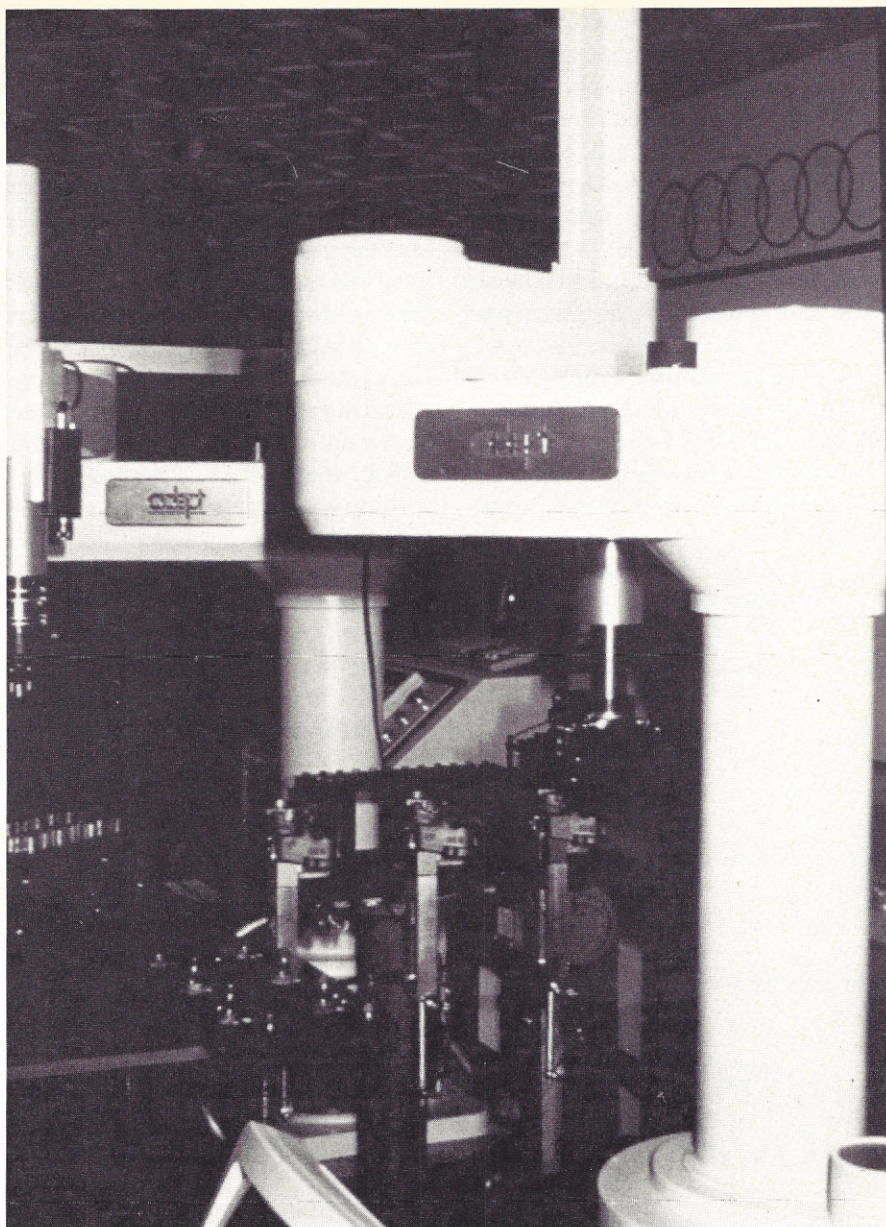


Figure 1. The two robots constantly exchange status reports and use state tables to prioritize tasks.

sor detects the gear is meshing with the first gear. Then the robot releases the second gear and drops it into place.

A computer-controlled screwdriver mounted inside the third axis, or "quill," of the assembly robot automatically fastens the four bolts. A torque sensor in the screwdriver monitors the screwdriver torque to assure the bolt is driven home. To detect a jammed bolt, another sensor in the spring-loaded head of the screwdriver detects whether the bolt head is compressed. If torque is sensed without the bolt's being fully inserted, a jam has occurred. Other possible problems when driving the bolts—such as missing screws, dropped screws, misaligned holes, or a jammed screwdriver—are also detected using these two sensors.

CELL COMMUNICATIONS

Most of the communication channels are straightforward. Since only the transfer robot requires information from the line vision systems, the vision processor resides in the transfer robot's controller and communicates to the transfer robot via the controller backplane. Similarly, the arm-

mounted area vision processor resides in the assembly robot's controller. All Adept-Vision systems are integrated into the Adept controller, so no additional mechanical or software interface is required.

The two sensors in the screwdriver are wired directly to the binary I/O ports of the assembly robot. Since only the transfer robot places housings onto the assembly stations, the magnetic presence switches for each station are wired into that robot. However, the contact switches on the assembly stations that indicate the correct placement of housings are connected to both robot controllers. The transfer robot needs to know that a housing is correctly placed before releasing its grip. Since there is a chance that a housing can accidentally stick and become unseated during gear placement, the contact switches also need to go to the assembly robot controller.

Finally, the two robots communicate status information to one another via an RS-232 serial communications channel. For example, the transfer robot can indicate to the assembly robot that a housing in Station #1 is ready for gear insertion. In addition, location information is traded to avoid collisions. The assembly

robot is notified to stay out of a particular station when the transfer robot is there.

THE ASSEMBLY PROCESS

The assembly sequence begins when the moving-line vision system recognizes a pump housing on the conveyor belt. The transfer robot frequently polls the vision system. When the housing is recognized and an assembly station is available, the robot tracks the conveyor and acquires the housing with an electromagnetic end effector. Immediately after the electromagnetic actuates, the contact switches in the gripper are checked to ensure that the housing is securely gripped. If the housing is present, the transfer robot places it in the open assembly station. If a housing is not sensed, the robot retracts to wait for another housing or performs another of its tasks.

During the transfer robot's move to the assembly station, it signals the holding pin in the assembly station to extend. When the magnetic presence switch indicates that the pin is extended, the robot places the housing on the station, checking the station contact switch before releasing the

EVERYTHING YOU NEED... \$279⁰⁰

Now it's easy to program the Heath-Zenith HERO-1® Robot with an Apple® II. HERO® Macros for the S-C Software 6800 Cross Assembler program in Heath's Robot Interpreter Language with easily remembered mnemonics. [For example, the line: 1130 > MVWRIM GRIP, OPEN, 60, FAST instructs the HERO® to open his gripper 60 units at fast speed. Motor position is expressed in base-10.]

The HERO® Macros come with 30 pages of documentation. Transfer to HERO® with ROBI... an affordable interface for the robotics experimenter... is simple.

- ROBI is a complete package. No additional hardware required for Apple® or HERO®.
- ROBI installs quickly in an Apple® II, II+, or IIfx. Once installed, no hardware changes are needed. Within minutes, you will be programming HERO®.
- With ROBI and the Cross Assembler, the programmer uses Apple®'s memory to write the program, and HERO®'s memory to run the program.
- Not "copy protected," archival copies may be made as needed.
- ROBI offers expansion potential.

VISA and MasterCard accepted.

BERSEARCH
Information Services

26160 Edelweiss Circle
Evergreen, Colorado 80439

The Cross Assembler with
HERO® Macros sells for
\$100.00; the ROBI Interface
sells for \$199.00. Both as
a package — \$279.00.

To order, or for more
information, call
(303) 670-6137.

APPLE® is a trademark of Apple Computer. HERO® is a trademark of Heath Electronics.

VISION ADVERTISERS: A UNIQUE OPPORTUNITY TO REACH MACHINE VISION'S HOTTEST MARKETS

VISION TECHNOLOGY

- Inspection
- Guidance
- Automatic Identification
- Process Control

"Vision Technology," an editorial and
advertising supplement for the
June '86 issues of

ROBOTICS ENGINEERING, SENSORS, and
BAR CODE NEWS, will reach the vision
market like no single vehicle!

- 80,000 Combined Circulation
- Distribution at VISION '86 &
ADVANCED MANUFACTURING
SYSTEMS
- More machine vision buyers per
advertising dollar!
- Advertising Closing: April 4, 1986

Call now for rate information and space
reservations!

North American Technology, Inc.
(603) 924-7136/7261.

part. If the contact switch indicates that the housing is not seated, a routine is executed to move the housing in small increments until properly seated. The transfer robot then leaves the station and signals the assembly robot that a housing is in place and waiting for gear insertion.

The assembly robot requests that a picture of the gear tray be taken whenever the robot arm is near the tray. The recognized gear information is fed into a software queue that is accessed by the assembly robot when it needs to acquire a gear. When the transfer robot signals that the housing is in place, the assembly robot acquires a mating gear and moves to the assembly station. Then a command

*Integrated vision,
integrated control,
and extensive sensory
communications
actually simplify an
assembly cell rather
than complicate it.*

is executed to move in a vertical direction while sensing for force overload. If an overload occurs, the robot turns the part about its axis to relieve the jam. Upon successful insertion, the robot returns to the tray and acquires a shafted gear.

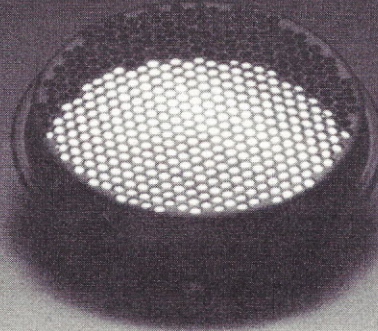
The shafted gear is placed in a similar manner but with two additional steps. The holding pin must be retracted when the shafted gear is placed, so the robot checks a magnetic presence switch to ensure that the holding pin is retracted. Also, as the robot moves in the vertical direction to place the gear, the force sensor is monitored to determine when the two gears have meshed.

After both gears are successfully placed, the assembly robot signals the transfer robot. The transfer robot has already polled the line vision system to locate a cover. It then places the cover on top of the housing assembly and "holds" the cover in place while the assembly robot is signaled to insert the first bolt. After the first bolt is inserted, the transfer robot leaves the station because the cover is now secured for the three remaining bolts.

When the gear insertion is complete and

Continued on page 24

What can stop a 650-ton locomotive in its tracks, keep a 7-billion gallon tank from overflowing, and help a blind man cross the street?



This can.

The Polaroid Ultrasonic Ranging System is an accurate, highly sensitive way to detect and measure the presence and distance of objects from 10.8 inches to 35 feet.

It controls industrial robots. And safeguards operators. Measures room dimensions at the press of a button. Warns a truck driver that he's in over his head. And more.

Polaroid introduces a new Environmental Transducer. An improved ultrasonic transducer (available in a sturdy housing) can withstand exposure to a wide range of hostile environments: rain, heat, cold, salt spray, chemicals, shock and vibration. Yet it's just as sensitive as the original transducer used in millions of SX-70 Sonar Autofocus cameras.

Get a \$2-million head start on your next product design. Polaroid spent over \$2 million developing the Ultrasonic Ranging System. But now you can get this technology in our Designer's Kit for only \$165. Or order just the individual components you need for your application.

How far can you take the technology? Call Polaroid's Applications Engineers at 617-577-4681 and find out.

Visit us at ROBOTS 10, Booth #2059

How to get \$2-million worth of technology for \$165.

To order your Ultrasonic Ranging System Designer's Kit, please send a check or money order for \$165 for each kit, plus all applicable state and local taxes, to: Polaroid Corporation, Ultrasonic Components Group, 119 Windsor Street, Cambridge, MA 02139.

____ Please send me ____ Designer's Kit(s). ____ Please send more information.

Name _____

Title _____

Company _____

Address _____

City _____ State _____ Zip _____



"Polaroid" and "SX-70"®

Polaroid

RE 4-86

**The editors of Sensors magazine
and the companies below*
invite you to join them
in the first national
conference and exposition
devoted exclusively to
sensor and transducer technology.**

Aleph International ☐ Amerace Corporation ☐ Azonics Corp. ☐ BLH Electronics ☐ Bruel & Kjaer Instruments ☐ Campbell Scientific Incorporated ☐ Crystal Technology, Inc. ☐ Druck Incorporated ☐ Dynisco ☐ Eaton Corporation Automation Products Div. ☐ Eaton Corporation Cutler Hammer Products ☐ Elmwood Sensors ☐ Endevco Div., Becton, Dickinson & Company ☐ Hottinger Baldwin Measurements ☐ Hy-Cal Engineering Unit of General Signal ☐ International Electro-Magnetics ☐ Kaman Instrumentation ☐ Kistler Instrument ☐ Massa Products Corporation ☐ Migatron Corporation ☐ Mikron Instruments ☐ Molytek, Inc. ☐ Namco Controls ☐ Motorola Semiconductor ☐ Omron Electronics ☐ Opcon Inc. ☐ Optical Technologies Inc. ☐ Paine Instruments ☐ PCB Piezotronics, Inc. ☐ Pennwalt Corporation ☐ Physical Acoustics Corp. ☐ Polaroid Corporation ☐ Precise Sensors, Inc. ☐ Pulsotronic Merten GmbH and Co., KG ☐ Raytek, Inc. ☐ Rechner Electronics Industries, Inc. ☐ Saab Systems Inc. ☐ Sangamo, Div. of Solartron Transducers ☐ Scanivalve Corporation ☐ Sencon Inc. ☐ Sensing Devices Inc. ☐ Sensor Developments, Inc. ☐ Sensotec, Inc. ☐ Sensym, Inc. ☐ Setra Systems Inc. ☐ Sick Optik-Elektronik Inc. ☐ Smith Research & Technology ☐ Spectron Glass & Electronics ☐ Sperry Sensing Systems ☐ Thunder Scientific Corp. ☐ Transamerica Delaval Inc./CEC Instruments Division ☐ Tri-Tronics Inc. ☐ Turck Multiprox, Inc. ☐ Universal Flow Monitors ☐ Validyne Engineering ☐ Viatran Corporation ☐ Vibro-Meter Corporation ☐ Xolox Corporation ☐ Yellow Springs Instrument Company Inc. ☐ Pepperl & Fuchs, Inc. ☐ R.M. Young Company

* Exhibitors as of January 10, 1986

SENSORS EXPO

O'HARE EXPOSITION CENTER, CHICAGO
SEPTEMBER 17 - 19, 1986

The response to SENSORS EXPO — the first conference and exposition devoted exclusively to sensor and transducer technology — has been enthusiastic on all counts.

A Call for Papers in this magazine produced a deluge of submissions from industry experts — papers reflecting the ever-increasing role of sensors in reshaping manufacturing, processing, materials handling, research and development, quality assurance, and robotics.

Inquiries for information on the program of professional education — currently being shaped by the editors of *Sensors* magazine — have been pouring in from design engineers, engineering and R&D managers, scientists, manufacturing and production executives, and corporate managers...

...decision-makers from industries including: automotive, aerospace and aviation, agriculture, communications, computers, consumer electronics, defense, food processing, heavy industry, medical device and instrumentation, petrochemicals, pharmaceuticals, and more.

This first-of-its-kind opportunity to reach the specifiers and buyers who are designing and developing products and systems with electronic sensing capability has also attracted many supplier companies, with many more to come.

SENSORS EXPO offers three days of learning — at the conference program, in the exhibit hall, and in the many informal exchanges with your colleagues from all parts of the country.

If you'd like more information about attending, circle the appropriate Reader Service Inquiry number below. The complete program will be sent to you as soon as it's available.

Or, if you'd like the opportunity to exhibit, face-to-face, to thousands of engineering, manufacturing, and production specifiers, circling the second Reader Service Inquiry number will get you a complete Exhibitor Package.

For further information about SENSORS EXPO, contact Susan Reuter at

Expocon Management Associates, Inc.
3695 Post Road
Southport, CT 06490
(203) 259-5734

For information about Attending, Circle 57
For information about Exhibiting, Circle 58

while the transfer robot is placing the pump cover, the assembly robot goes to the bolt rack and acquires the first bolt. The compression sensor is checked before removing the bolt from the rack to ensure that the head has fully seated. If it has not, the sensor directs the robot into a search routine. The screwdriver is turned on in reverse for a preset time to remove the bolt. The compression sensor is checked again to ensure that the bolt is present in the screwdriver head. If the bolt is missing, the robot returns to acquire another bolt. Once the bolt is securely in the screwdriver and the transfer robot has sent the go-ahead signal, the assembly robot inserts the bolt, using the two available sensors.

When the transfer robot has left the assembly station, the assembly robot goes on to insert the other three bolts and complete the pump. The transfer robot is signaled to remove the pump from the assembly station and place it in a pallet of finished pumps.

This application sequence results in an average assembly time of 40 seconds per pump. Several changes to the cell design could improve this throughput rate. First,

Table 1	
Assembly Robot Controller	Transfer Robot Controller
Cell Control <ul style="list-style-type: none"> • Robot-to-Robot Communications 	Cell Control <ul style="list-style-type: none"> • Robot-to-Robot Communications
Robot Control <ul style="list-style-type: none"> • State Table Polling • Executing Highest Priority Task Subroutine • State Table Updating 	Robot Control <ul style="list-style-type: none"> • State Table Polling • Executing Highest Priority Task Subroutine • State Table Updating
Vision Control <ul style="list-style-type: none"> • Recognize and Locate Gears in Tray 	Vision Control <ul style="list-style-type: none"> • Recognize and Locate Pump Housings and Covers on Moving Conveyor

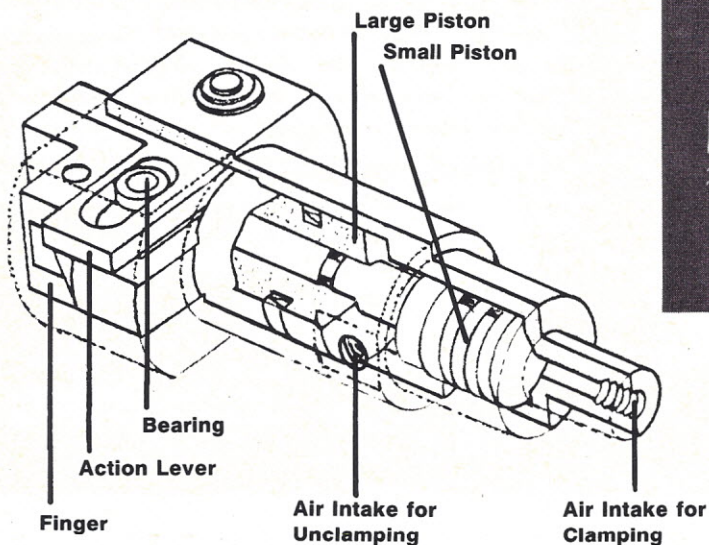
the bolts could be automatically fed into the screwdriver rather than acquired from a rack. Also, multiple screwdrivers could be used. Second, a simple pneumatic actuator could hold the cover in place so the transfer robot would be free to do other tasks. Third, with these changes the transfer robot would spend much of its time waiting for the assembly robot, so the cell should be designed so that one transfer robot feeds two assembly robots. With these changes, the assembly time might be reduced to 15 seconds per pump.

CELL PROGRAMMING AND CONTROL

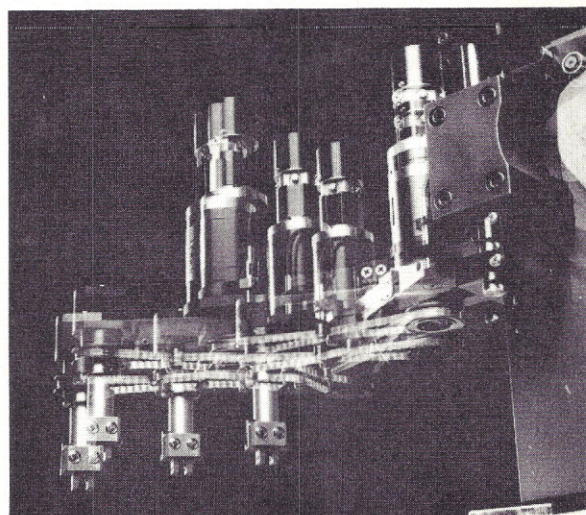
Since there are three assembly stations and the mix of tasks waiting to be accomplished changes from moment to moment, task priorities are assigned based on the "state" of each assembly station. Each robot has a set of state tables that define the order of operation, the relative priority of each task, and the current status of the pumps in each of the three assembly stations. The state tables are continuously scanned and the highest priority task is

High Precision Parallel Motion Robotic Grippers

- Parallel clamping/unclamping eliminates deflection in grasping dimension.
- Simplicity in design allows small size, smooth operation, and quick response.
- High precision clamping mechanism ensures high precision chucking.



DISTRIBUTOR/OEM INQUIRIES INVITED



ASSEMBLY ROBOT INQUIRIES WELCOME

CORET & COMPANY, LTD.
Shimbashi Ekimae Bldg. No. 1
20-15, 2-chome Shimbashi
Minato-Ku, Tokyo 105, Japan
Phone 03-573-1721
Telex 2523676 TESH J
Facsimile 03-461-5698

executed. Each specific task—such as the task of placing a housing onto an assembly station for example—is written as a subroutine that the robot calls up and executes when the task reaches the highest priority. Because of state table programming, the assembly tasks described earlier are never followed without interruption at any one assembly station. The actual order of tasks is determined in real time, based on the highest priority task at all three stations.

To illustrate the effect of state table programming, we will compare two different situations. Let's assume two assembly stations have pumps and the third station is empty. The transfer robot polls the moving-line vision system and learns that another pump housing is available. In one situation, the assembly robot is inserting gears and does not require the transfer robot. Getting another pump for the third assembly station becomes the highest current priority and the transfer robot acquires the pump. In the second situation, the assembly robot has already inserted the gears and is waiting on the transfer robot to place a cover. Getting a cover is a higher priority task than getting a housing because the assembly robot will be idled if the transfer robot takes time to get another housing. So the housing is ignored on the belt and the transfer robot gets a cover instead.

Table 1 illustrates the functions of the cell control program and the functions of each robot's program. As shown, the cell control function does not require a separate programmable controller. The Adept robot controller can simultaneously and asynchronously run two separate programs and can therefore act as both the robot controller and the cell controller. For this cell, it was not necessary to designate a control robot versus a slave robot. Instead, both robots run a cell control program that continuously updates the state tables.

Both the cell control programs and the robot control program are coded in VAL-II™, Adept's programming language. (VAL-II is a trademark licensed to Adept Technology, Inc). The vision systems described earlier are also integrated into the controller and programmed in VAL-II.

SUMMARY

The complete assembly of an automotive oil pump in one two-robot cell illustrates

state-of-the-art vision-guided robotic assembly. Most important, it illustrates that integrated vision, integrated control, and extensive sensory communications actually simplify an assembly cell rather than complicate it. Because of robot guidance vision, part presentation is simplified and more flexible. Since the vision is integrated in the robot controller, the addition of vision does not complicate the overall cell design.

With built-in communications capacity, the sensors needed to verify the process and respond to errors are easily added to the cell. Because of integrated cell control,

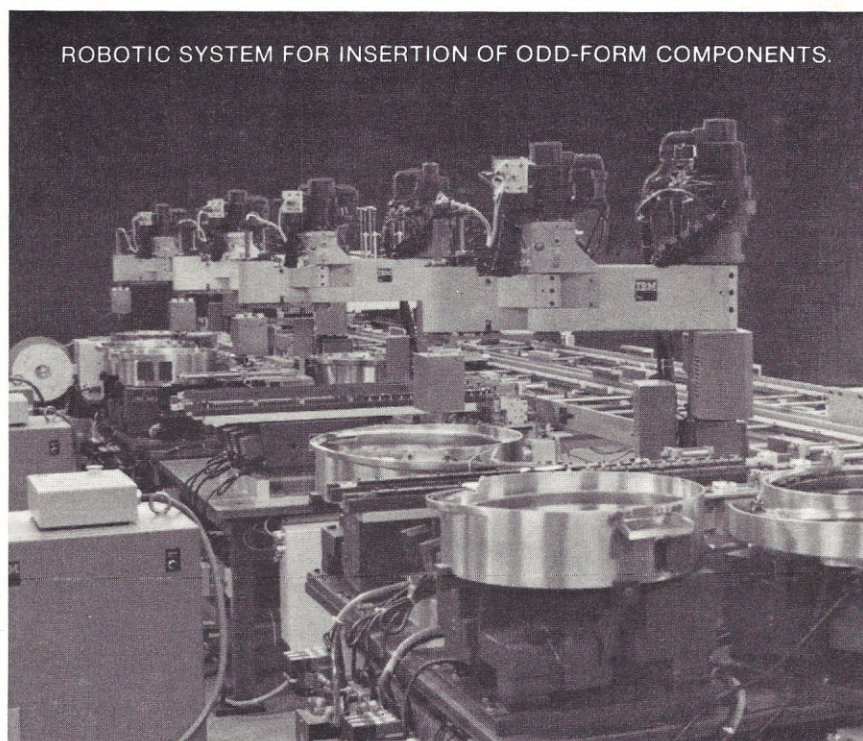
real-time task assignment is possible without adding a cell controller, and the two robots' motions are smoothly coordinated within overlapping work envelopes.

Gordon Mayer is Technical Marketing Director and Elaine Ide Wood is Market Development Manager for Adept Technology, Inc.

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

3	13	23
Excellent	Good	Fair



Automation Systems for the Electronics Industry

GEIZER

SINCE 1968

PC Board Assembly

Hybrid Circuit Finishing

VLSI Test Handlers

Coil Testing and Finishing

Component Tinning and Packaging

Gelzer Systems Company

4199 Weaver Court S.,
Hilliard, Ohio 43026
614/771-0117

The Simulation and Programming of Multiple-Arm Robot Systems

James F. Callan

Silma Incorporated
2111 Grant Road
Los Altos, CA 94022

Today's automated factories often employ robots, vision systems, tactile sensors, and programmable controllers. Many times there are multiple robots involved, but in separate workcells. It is rare to see two or more robots truly cooperating, with overlapping workspaces and interspersed actions, despite the fact that close cooperation between robots can greatly increase the efficiency and flexibility of workcells.

Fixturing can often be shared, and idle time for robots and other equipment minimized by effective scheduling. Some complex assembly operations cannot be automated at all without the use of multiple cooperating robot arms. The main obstacle to the implementation of this form of robotic automation is the complexity of the planning and the programming required. It is here that computer-based robot simulation systems have much to contribute.

THE ROLE OF COMPUTER SIMULATION

Simulation systems allow the user to experiment with various workcell layouts, simulate the kinematic and dynamic behavior of specific robots, and generate programs for them off line. Unfortunately, most simulations are unable to handle more than one robot at a time, rendering them unusable for planning and programming the automation systems that most need their help: multiple-arm robot systems. To address this need, Silma, Inc. has developed the CimStation™ (Photo 1) to which a multiple-arm simulator has recently been added.

CimStation is used to create and modify a computer-based three-dimensional model of one or more robotic workcells, for writing robot programs, and for creating computer graphic animations of particular robots executing their programs. The user observes whether robots can reach their goal points and whether any collisions will occur, and receives cycle time estimates. The operator can then

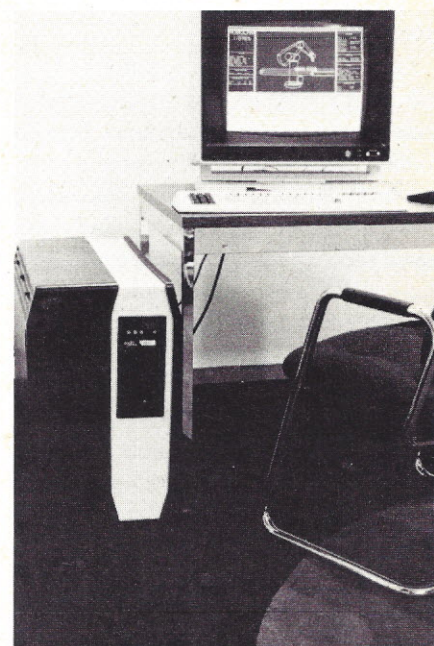
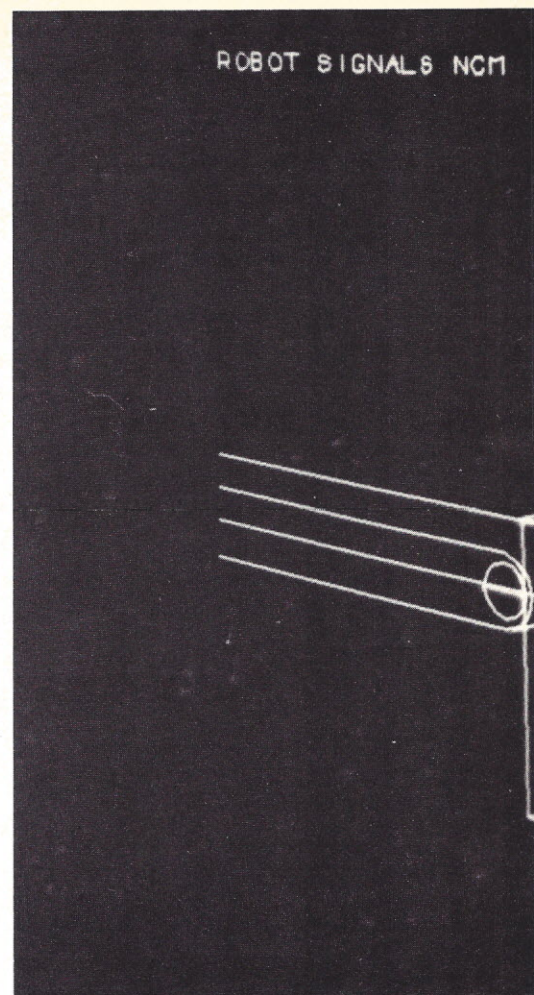


Photo 1. The CimStation has multiple-arm simulation capability.

easily modify the workcell layout, change the program, or even try out different robots. This process of modification and

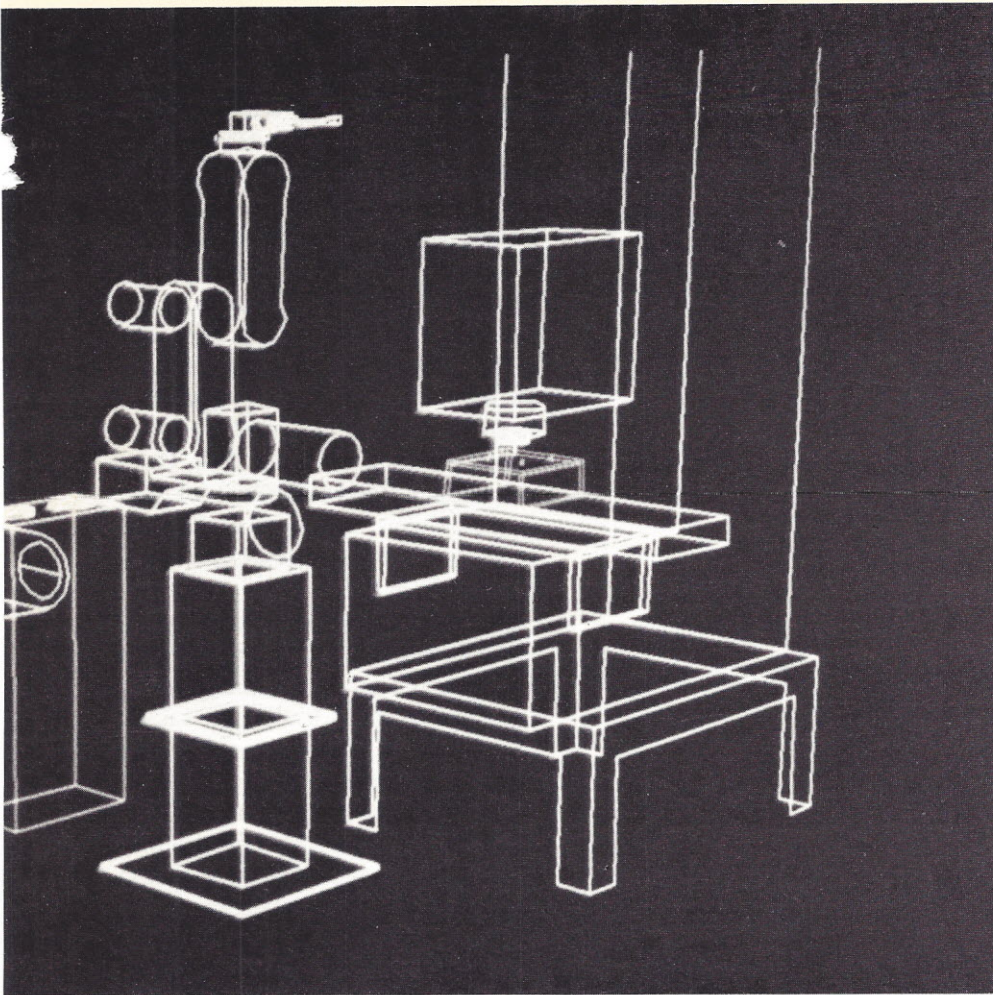


Photo 2. The robot shares its workcell with an NC milling machine, requiring tight communications to coordinate the task and to prevent collisions.

INTER-DEVICE COMMUNICATION

Even simple robot systems like the one depicted in Photo 2 require a surprising amount of inter-device communication. In this example, a robot picks up plastic blanks from a conveyor, loads them into a two-position fixture for milling by an NC machine, and later extracts the milled pieces from the fixture and palletizes them. The milling of one blank is overlapped by the palletizing of the previous piece and the pickup of the next blank. For maximum efficiency, the robot and the NC cutter enter and leave their common workspace just in time to avoid collisions, requiring tight communications between the robot and the cutter.

Additionally, the robot monitors signals from an optical sensor on the conveyor, from its own gripper, and from a pallet operator. It also issues signals to the conveyor and to a production control computer, as well as sounding a "pallet full" alarm for the operator. The communication for this system, really a rather simple one compared to many others, is diagrammed in Figure 1. The communication complexity compounds rapidly when multiple robots and tools operate in synchrony. Experienced robot system designers report that in elaborate systems, communication is often the main aspect to be debugged.

Simulation of multiple devices is made possible by a concurrent programming language that is the basis for CimStation. SIL™ (for the SILMA language) is an extension of Pascal designed for automation programming. SIL extends Pascal in two important ways: it includes primitives for concurrency, and it is implemented in a

simulation continues until the designer is satisfied with the design, the choice of robots and other equipment, the system's cycle time, etc. Programs to drive the actual robot are also generated.

CimStation permits several robots to be present in the simulated workcell, along with vision systems, touch sensors, programmable controllers, NC machines, conveyance devices of various kinds, and so forth. The user generates not just one robot program, but rather a program for every robot and every other "active" device in the system. The programs contain not only commands to move arms and operate end effectors, but also commands for communication with other programs (simulating other devices) running concurrently. Communication takes place via signal and wait primitives. A program can signal information to another program, wait for a signal, or interrupt another program, temporarily redirecting its operation to an interrupt service routine. Data can pass from one program to another to simulate, for example, a vision system's passing position and orientation information to a

robot. Among the devices that can be simulated is a programmable controller, whose program contains no motion commands but often includes exceedingly complex communication commands. There is no limit to the number of devices that can be present in the system.

Simulation provides a way to automatically detect and report errors of several kinds, such as goal positions out of reach, joint limit violations, and maximum acceleration/velocity limit violations. Other error conditions can be detected visually from the monitor, notably collisions and "close calls." Finally, simulation permits verification of the correctness of communications between devices. Programming of interaction between cooperating devices is notoriously difficult to get right. Subtle bugs are common and debugging is arduous and time-consuming. Simulation is a great aid to this kind of debugging because the turnaround time in running through a simulation, detecting a bug, and implementing a fix, is much less than the time required for on-the-floor debugging.

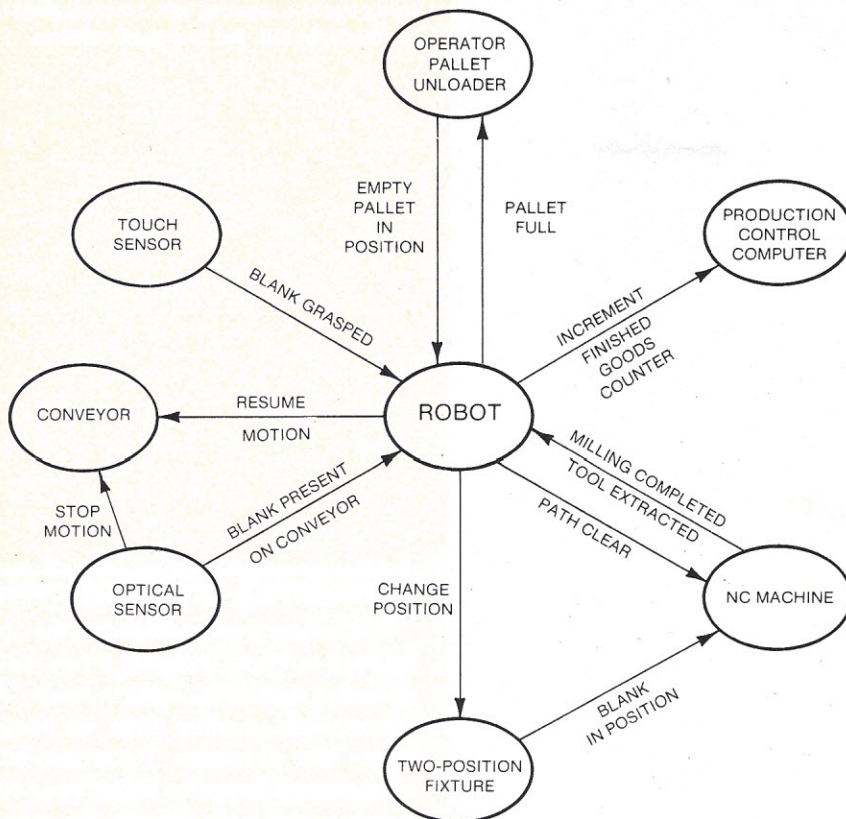


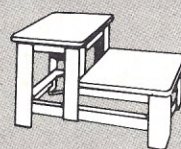
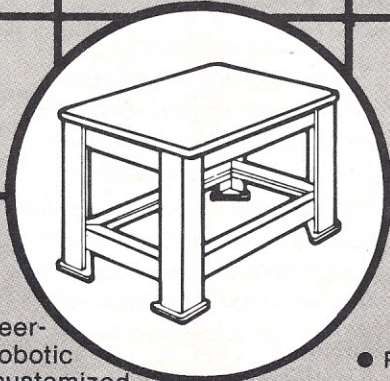
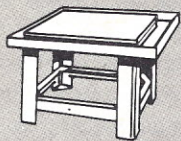
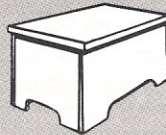
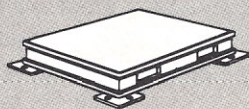
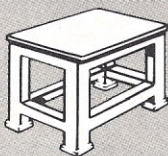
Figure 1. The robot avoids collisions with other machinery in its workcell by sending and receiving a number of signals.

fully interactive programming environment, like that of BASIC or LISP. Individual SIL commands can be executed interactively, with their effects immediately visible on the screen. Interactivity is very important for simulation purposes, because it allows the user immediate feedback about the effects of his actions. (The importance of interactivity for robot programming is well recognized; the majority of robot languages are interactive.) Alternatively, complete SIL programs can be compiled and run. Compiled SIL programs are as efficient as their Pascal counterparts. The usual penalty of an interactive system, namely, lack of efficiency for complex computations, is therefore not present in SIL.

CimStation can be extended by software packages that automate many of the difficult aspects of automation programming. For example, in particular applications, CimStation has been enhanced by algorithms which—in a sense appropriate to the application in question—automatically select the best scheduling of multiple arms from among a vast number of alternatives. A simulation capability thus can be regarded as an essential prerequisite for the automation of design and programming functions, as well as a tool directly employed by the human designer.

BRUTE MACHINE BASES

Customized To Your Needs at Standard Prices



Reduce manufacturing costs and design time! Versatile BRUTE BASES are engineered to meet your robotic needs—built and customized to your needs, specs and modifications at Standard Prices. It's "Base-IC Economics!"

- Special Burnouts
- Shot Blasted—Prime Painted

- Precision Ground Top

- Welded Steel Construction

- Standard or Modified Design

Shown above are representative BRUTE designs. CHALLENGE US to build a base to your design and specifications!



Write for our new FREE Idea File!
AMERICAN GRINDING AND MACHINE COMPANY
2000 N. Mango Chicago, IL 60639
IN A HURRY? CALL OUR "HOT LINE"! (312) 889-4343

SIMULATING THE DYNAMICS OF MULTIPLE ARMS

True multiple-arm systems—those with overlapping workspaces and tight timing (Photo 3)—impose the greatest demands on a robot simulation system. Real robots follow complex paths in space as they move from point to point. Their speed of motion is generally compounded from trapezoidal acceleration/velocity/deceleration curves for each of their joints and they have built-in rules for choosing from among many kinematic solutions to reach designated goal points. Coarse approximations of the behavior of real robots may suffice for planning certain simple applications, but when planning intricate multiple-arm systems, such approximations can spell the difference between predicting and failing to predict collisions, between bottlenecks identified and bottlenecks missed, between performance rates known accurately and not known at all, between systems justified and systems never imple-

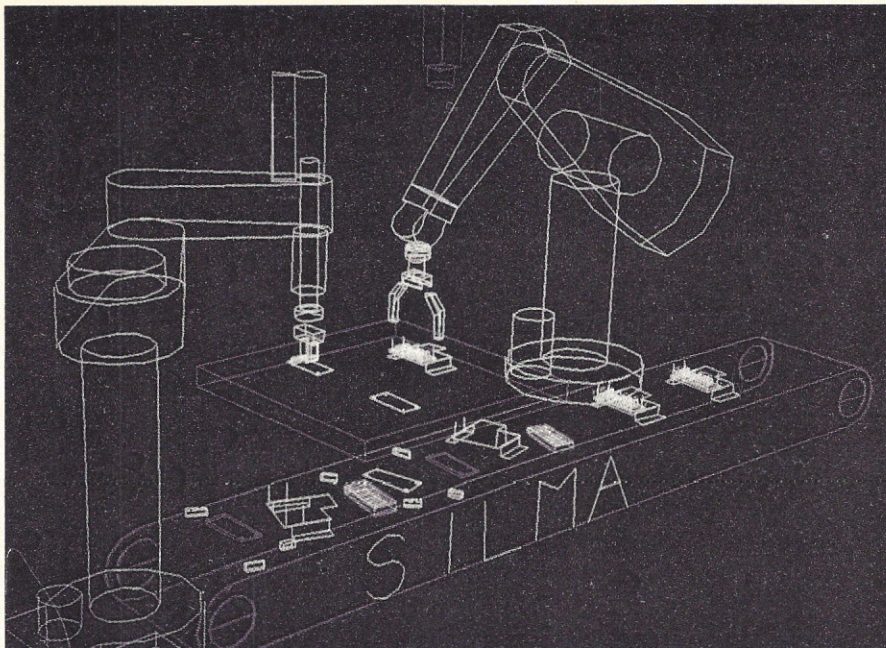


Photo 3. When designing a multiple-arm system, the algorithms for path planning and selection of kinematic solutions must be those used by the robot being simulated.

mented, and between systems that work and systems that do not. For all these reasons, it is imperative that the computer simulate robots the way they really work. Anything less is of little value.

A principal design goal of CimStation has been fidelity of simulation, a fidelity that requires that the same algorithms for path planning and selection of kinematic solutions be used in each simulation model

precisely as they are employed by the robot being simulated. It is not sufficient to use generic inverse kinematic and path planning routines. Only a robot-by-robot approach will work.

CONCLUSION

The continued spread of robotic automation depends on successful implementation of more and more complex robotic systems. As complexity rises, the feasibility of on-the-floor programming decreases. In the not-so-long run, simulation will become not just a convenience but a necessity for making the design and programming of complex multi-robot workcells possible.

James F. Callan is a Vice President at Silma, Incorporated.

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

4	14	24
Excellent	Good	Fair

INTELLIGENT MACHINES BEGIN WITH INTELLIGENT CHOICES

Good decision making depends on accurate and timely information. The Aerospace Database provides rapid access to the most comprehensive online source of AI and Robotics information. The Aerospace Database is:



Unmatched in diversity and depth:

- Cybernetics
- CAD/CAM techniques
- Robotic welding
- End effectors
- Systems integration
- Computerized simulation
- Adaptive control
- Servo control
- Computer vision

A convenient and reliable resource:

- Online access through your PC, data terminal, or communicating word processor.
- Updated semi-monthly
- International scope
- Multi-disciplinary coverage
- Rapid document delivery

Mail to: **Aerospace Database Services - AIAA/TIS**
555 West 57th Street-Suite 1200R
New York, N.Y. 10019

Or call: 212/582-4901

NAME: _____ TITLE: _____

COMPANY: _____

DIVISION/DEPT.: _____

ADDRESS: _____ PHONE: _____

CITY: _____ STATE: _____ ZIP: _____

☐ Please send information on The Aerospace Database.

☐ I currently use online retrieval systems. They are: _____

☐ I currently do not use an online retrieval system.

Case History of an Automated Assembly System

Frank C. Romeo

FARED Robot Systems, Inc.
7410 Pebble Drive
PO Box 185579
Fort Worth, TX 76181-5579

When Xebec decided on a printed circuit board testing, storage, and bracket assembly system for its Gardnerville, Nevada, facility, it contracted FARED Robot Systems to design, develop, build, and install it. This system was to handle several board types simultaneously and receive boards from the manufacturing facility on demand, meter them to automatic test stations, repair stations, and board trim and bracket installation stations (Photos 1 and 2). The flow diagrams were developed in conjunction with Xebec's

engineering staff to meet its preferred sequence of operations and throughput. A Wiebe Systems programmable distribution system for part transportation, IBM 7540 robots, and FARED proprietary board totes, board handling, and FARED-generated custom software were the major elements used in this application.

A typical testing cycle is as follows: the Wiebe system indicates a tote is shot pinned in the working-good-part location, and that another is shot pinned in the reject tote location. The robot searches for a board, and, locating one, removes it. It changes the board from a vertical to a horizontal position and locates it on testers that have been modified with extended pins. The robot then signals the tester to lower the lowerator platform, turn on the vacuum, and initiate the appropriate test.

If the board under test is defective, it is removed and the robot presents its bar-coded label to a stationary bar code reader. The serial number is transmitted to the SC1-1033, a FARED information multiplexer, and the error code is requested from the tester. The SC1-1033 merges the two pieces of information and both are sent to the PC host for retrieval during repair. The load and unload cycles are each 12 sec. and the scanning cycle is 9 sec. If a board is misplaced in the grippers, or will not load into the tester or a tote, it is placed in a holding area. Using adaptive assembly and error recovery techniques, machine stoppages have been designed out as often as practical.

Accepted boards are stored until needed for shipping. Bad boards are also stored

during first shift, lunch breaks, and any second-shift or third-shift operation, which allows three-shift testing and single-shift debugging and repair. When shipping personnel are available, the system sends good boards from the storage area to a bracket installation station where the boards are removed from the tote and a mounting bracket is installed. After the bracket is installed, a processing tab is sheared from the face of the board and the board is sent to a packaging station.

The PC board testing line (Photo 3)

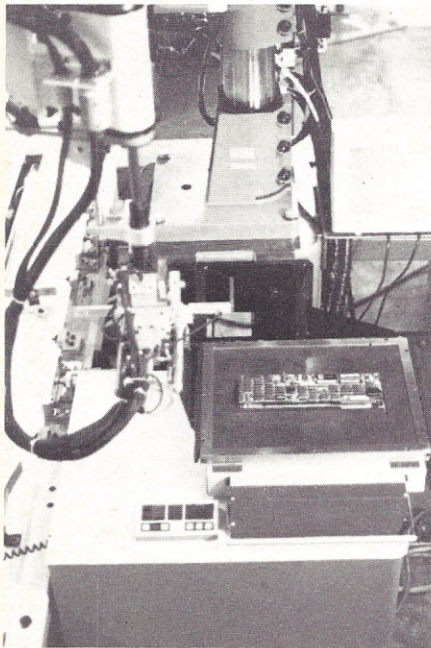


Photo 1. The robot picks up a printed circuit board, rotates it, places it onto a tester, and finally puts it into an accept or a reject tote.

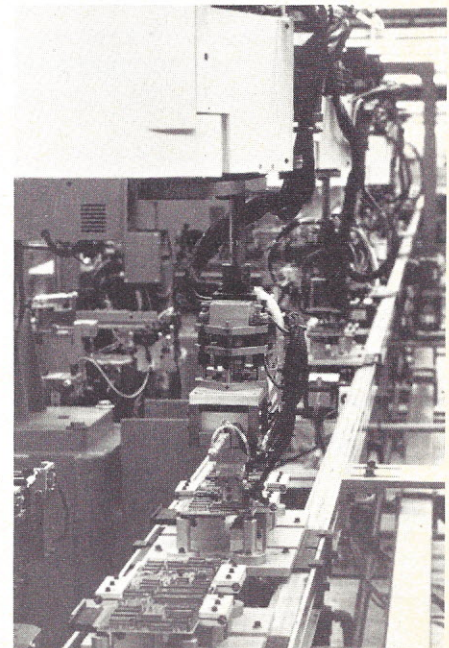


Photo 2. The multi-station circuit board assembly system includes feeding and lead-forming tooling for a variety of odd-form electronic components.

presents new problems for robotics. The robot must cover the full working envelope of functional testers, short circuit testers, and large transport totes, and still maintain repeatability and accuracy. Larger boards present an additional problem—the part does not easily provide a flat plane. Board warp and planar distortions were the most difficult problems to solve.

All boards are loaded into a custom tote after wave solder and inspection. All totes from the solder station are directed to the storage rack. The storage rack can function in a FIFO or LIFO method; this installation uses FIFO. From the storage rack, which can hold 300 totes with 14 or 30 boards each, an Allen-Bradley Series 230 or 2/05 PLC directs totes to work stations on demand. A zone control feature used by Wiebe makes tote identification unnecessary, in that it allows the user to define work zones and single totes to pass through one zone at a time; the result is considerable savings on a tote ID system.

The workcells on the distribution system are identical, regardless of function. Each contains a filled tote with boards to be tested and an empty tote for rejects. The available slots in the reject tote are electronically stored, to be released when full or if an operator at a repair station requests more work. The totes supplying boards to be tested are assumed full, but only a small cycle time penalty is incurred if a slot is empty. The totes are always locked in place for robotic work.

One of the key features of this system is the tote currently being tested. It consists of two distinct parts. An outer plastic box open on the top allows transportation without any board contact. The inner section of the tote, which is completely independent from the outer shell, is an aluminum frame with slots milled in the sides. This frame also contains four shot pin receptacles. These seats allow each tote to mate with corresponding shot pins driven by the stop stations. Shot pinning the frame is the only way to guarantee repeatable tote location. The milled slots also ensure that all boards are spaced on precision centers. The design goal was PC board location within ± 0.015 in. FARED found this precision less costly than a vision system interface for slot location; without this precision control, an unacceptable number of misses will occur.

The robot support is a precision-machined casting. The transport, testers, and

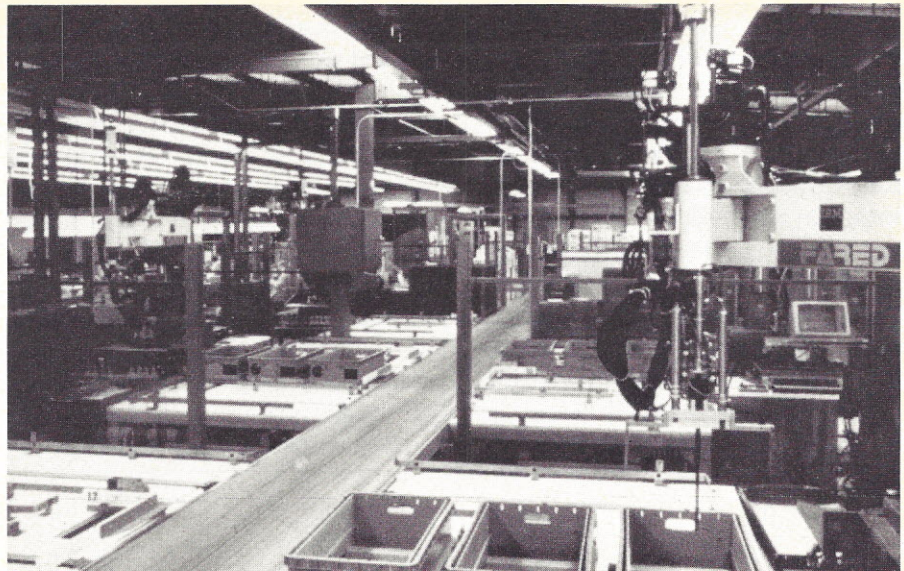


Photo 3. On the testing line, the robot covers the full working envelope of functional testers, short circuit testers, and transport totes while maintaining repeatability and accuracy.

any other peripheral equipment are attached to this stand. Precision casting defines the robot's world coordinate system, allowing maintenance of accuracy and exchange of components without reteaching the entire robot program. The IBM robots used in this system offer the accuracy and repeatability necessary for the

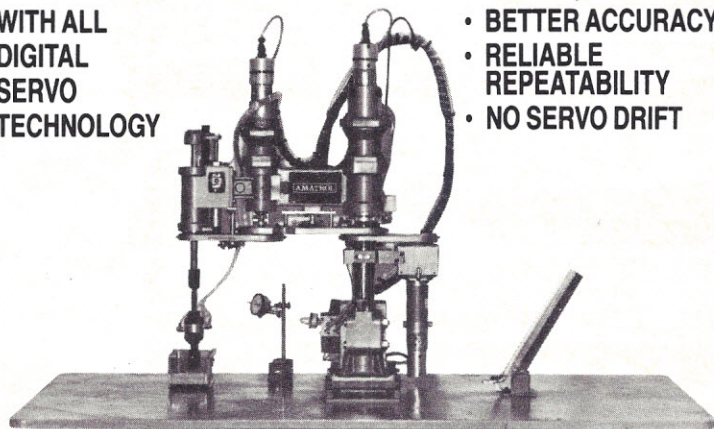
task. The "Z" stroke was modified to allow 15 in. of movement, thereby providing adequate stroke for board removal from the tote. The IBM 7540's mean time between failure of 2000 hours was instrumental in selection of this machine. It also fulfills all the other selection criteria outlined in the PC board assembly system.

THE JUPITER ASSEMBLY ROBOT SYSTEM

HIGH PERFORMANCE HERE TODAY

WITH ALL
DIGITAL
SERVO
TECHNOLOGY

- BETTER ACCURACY
- RELIABLE REPEATABILITY
- NO SERVO DRIFT



Assemble printed circuit boards with virtually zero operator attention. Great for solder masking too!

User friendly menu-driven or lead-thru programming means faster set up time.

Capacity to 13 lbs. at 55 ips.

Application Assistance and factory training. Let Amatrol show you how.

Workcell Tooling can be designed and furnished by Amatrol.

Grippers customized or standard designs. Components or complete turn key systems.

Write for more information

AMATROL

Amatrol, Inc.
P.O. Box 2097, Jeffersonville, IN 47131
(812) 288-8285

The gripper design is a patented device developed at FARED, consisting of two moveable side guides that are driven by a precision parallel gripper to ensure proper centering of the board. Another stationary guide is placed at the top of the board. An independently driven loading tang pulls the board out of the tote and into the side and top guides. When the board is pulled into the guides, sensors indicate proper board placement and the side guides close, centering the board.

To facilitate unloading the board into the tester, two modifications were made

to the bed-of-nails test head. First, FARED extended the guide pins 1 in. to allow the robot to load the board directly onto the pins. Then the bed of nails was fitted with a small elevator-lowerator platform to provide a consistent placement and pickup location for the robot. To unload the board into a tote, the side guides are released while maintaining their guide position and pushing the board into the tote slot until it is fully seated. The gripper used many sensors to confirm each action and the presence of the board. It is mounted on a tool changer that intercon-

nects all air and electrical connections. In this test system two boards were run concurrently, making the tool changer mandatory.

System control involves a three-level hierarchy. The robots control everything inside their work area. If any control functions are required that the robot controller cannot supply, the cell's needs are supplied by the Allen-Bradley PLC or the host IBM PC. Communications to these devices are handled serially via RS-232 to the IBM PC or digitally to the Allen-Bradley PLC. Services needed from the computer are coordinated by the robot controller. The robot stations are designed to be as autonomous as practical. If the PC goes down or is taken off line, the system carries on.

All serial communications are handled by a multiplexer, the FARED SC1-1033. Each line is buffered and the multiplexer also functions as a cross-compiler. This allows all serial communicating devices to be networked in near real time. The main console display prompts the operator with error messages and diagnostic information. The host also records operating statistics such as system run time, number of parts produced, the performance of each cell, the number of rejects cell by cell, the average cycle time of the board repair operations, and so forth. The multiplexer enhances the system by allowing orderly startup and shutdown. The user can address each robot or ancillary device individually or concurrently, giving the console operator complete control. Information is passed on to an IBM-supplied CIM system that generates management information as required.

This system, and others like it, are in the vanguard of new options available to electronics manufacturers. As the electronics and communications industries continue to expand rapidly, fierce competition is forcing profit margins down. Robotics offers the cost-effective edge necessary to make the high quality/low-cost products the marketplace demands.

Frank C. Romeo is Executive Vice President of FARED Robot Systems, Inc.

Circle 33

The Amazing A-BUS

Hobbyists, Engineers, Scientists, OEMs, and universities, the A-BUS is for you!

What is the A-BUS? The A-BUS is the best way to connect a variety of **Input and Output** cards (such as analog converters, relays, sensors, motor controllers, etc.) to your computer.

A typical A-BUS system consists of: • An Adapter Card and a Cable to convert your computer to the A-BUS standard • The A-BUS motherboard, with several slots in which you plug the different Input and Output cards • Your choice of cards listed below to fit your application. (Many more cards will be released soon.)

The "A" stands for Amazing, and here is why:

The A-BUS is designed to work with many different computers: IBM PC,XT,AT; Apple II's; and TRS-80 Models I,III,4,4P,4D,100,1000. Should you ever move to another system, your investment is protected. Only the low cost adapter card has to be changed!

The system is expandable to meet current and future needs easily. Motherboards can be daisy chained for up to 20 cards.

Low cost and reliability will ensure your project success.

A-BUS Adapter for IBM's and compatibles. Uses one short slot **AR-133...\$69**

A-BUS Adapter for Model I Plugs into 40-pin I/O card edge (on KB or E/I) **AR-131...\$39**

A-BUS Adapter for Models 3,4,4P,4D Plugs into 50-pin I/O bus. **AR-132...\$49**

CABLE (3 ft.) to connect computer to A-BUS. One required for each system. **CA-163...\$29**

A-BUS Motherboard, for up to 5 cards (not needed if using only one card) Includes sturdy anodized aluminum frame and card guides. **MB-120...\$95**

MANUAL All the A-BUS products include a detailed user's manual.

A-BUS Relay Card: RE-140...\$129

This industrial grade output card includes 8 relays. (Contact rated 3 Amp @ 125V) All the decoding necessary is included which means that you can connect up to 64 cards (which is 512 relays.) Easily controlled using "OUT" commands. For example OUT 1,0 turns all the relays off on card #1. Eight LED's show the states of the relays.

A-BUS Isolated Digital Input Card: IN-141...\$49

This optically isolated input card makes it safe and easy to connect external devices (switches, thermostats, keypads) to your computer. Simple INP commands read the status (ON or OFF) of the eight inputs. Inputs can be Voltage (5-24V), Current (5-10mA), or switch closure. Full address decoding allows up to 64 input cards (that's 512 channels) per computer.

A-BUS Analog Input Card: AD-142...\$119

8 channel 8 bit Analog to Digital converter. Your computer can read voltages, temperatures, pressures, light levels, etc. • Input range: 0 to 5.1 Volts. • Resolution: 20mV. • Conversion time: 120 microseconds. In BASIC, you can take up to 100 readings per second. • Port address: selectable. Up to 64 Analog-80's can be connected to your computer for a total of 512 channels!

An optional Amplifier board can be added to read millivolts: AM-169 \$29

A-BUS Dual Stepper Controller: ST-143...\$69

Don't be afraid of stepper motors anymore. The special package (below) includes everything you need to get familiar with steppers: • Controller card drives 2 steppers (12V bidirectional) ST-143...\$69 • Stepper: 48 steps per revolution, up to 300 steps/second, 1/4" shaft. MO-103...\$15 • Power supply PS-126...\$10

Special Package: Controller, two steppers and power supply: PA-181 \$99

SPECIAL Steppers: MO-103...4 for \$39

12V, unipolar, 7.5", 36 ohms, 1/4" shaft, 300 steps/second. Copal mfg model SP-57, same as Airpax K82701-P2. Regularly \$15 each.

A-BUS Prototyping card: PR-152...\$14

Protocard is 3 1/2 by 4 1/2 inches, and will accept up to 10 IC's

CABLES: Standard and Custom

Send for our standard cable flyer and our worksheet for custom cables.

ALPHA Products
79 04 A Jamaica Ave., Woodhaven, NY 11421

800-221-0916

Orders Only. NY & info call

(718) 296-5916

Hours: 9-5 Eastern Time

Add \$3.00 per order for shipping.

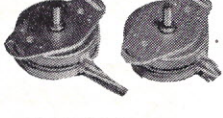
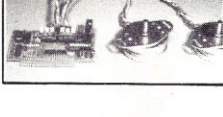
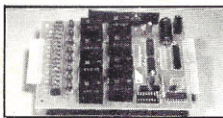
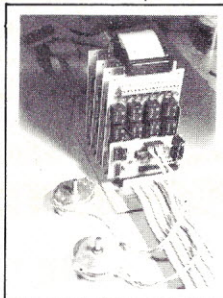
We accept Visa, MC, checks, M.O.

C.O.D. add \$3.00 extra.

N.Y. residents add sales tax.

Shipping to Canada is \$5.00

Overseas, FPO, APO add 10%



**SPECIAL
4 for \$39**

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

5	15	25
Excellent	Good	Fair

SUCCESSFUL
MANUFACTURING REQUIRES VISION...

VISION '86

CONFERENCE and EXPOSITION

June 2-5, 1986

Cobo Hall • Detroit, Michigan

To remain competitive in today's manufacturing environment, you need vision...machine vision. It's a technology that helps you boost productivity, improve product quality, and reduce overall manufacturing costs. At VISION '86 you'll see all the latest machine vision equipment on display at the show. Conference sessions will examine robot control & machine guidance, electronics, consumable goods, durable goods, 3-D vision systems, research and development, algorithms, hardware architectures & image acquisition, and industry trends. Make your plans today to attend VISION '86...for complete details, use the clip-out form below or call 313/271-0777.

Exposition Sponsored by:
Automated Vision Association
and
Society of Manufacturing Engineers

Conference Sponsored by:
Machine Vision Association of SME
and
its *Vision Quarterly*

VISION '86

Please send me complete information about:

- ☐ Attending the conference
- ☐ Attending the exhibits
- ☐ Exhibit rental
- ☐ Presenting a paper at future VISION events

Name _____

Title _____

Company _____

Address _____

City _____ State _____ Zip _____

Telephone _____

Mail to: Vision '86 Public Relations
One SME Drive
P.O. Box 930
Dearborn, MI 48121

TOTAL CONTROL with LMI FORTH™



For Programming Professionals: an expanding family of compatible, high-performance, Forth-83 Standard compilers for microcomputers

For Development:

Interactive Forth-83 Interpreter/Compilers

- 16-bit and 32-bit implementations
- Full screen editor and assembler
- Uses standard operating system files
- 400 page manual written in plain English
- Options include software floating point, arithmetic coprocessor support, symbolic debugger, native code compilers, and graphics support

For Applications: Forth-83 Metacompiler

- Unique table-driven multi-pass Forth compiler
- Compiles compact ROMable or disk-based applications
- Excellent error handling
- Produces headerless code, compiles from intermediate states, and performs conditional compilation
- Cross-compiles to 8080, Z-80, 8086, 68000, and 6502
- No license fee or royalty for compiled applications

Support Services for registered users:

- Technical Assistance Hotline
- Periodic newsletters and low-cost updates
- Bulletin Board System

Call or write for detailed product information and prices. Consulting and Educational Services available by special arrangement.

LMI Laboratory Microsystems Incorporated
Post Office Box 10430, Marina del Rey, CA 90295
Phone credit card orders to: (213) 306-7412

Overseas Distributors.

Germany: Forth-Systeme Angelika Flesch, D-7820 Titisee-Neustadt
UK: System Science Ltd., London EC1A 9JX
France: Micro-Sigma S.A.R.L., 75008 Paris
Japan: Southern Pacific Ltd., Yokohama 220
Australia: Wave-onic Associates, 6107 Wilson, W.A.

In The Robotics Age™

Edited by Stephanie vL Henkel

SCIENCE & TECHNOLOGY

A growing demand from end users that the robots they buy live up to manufacturers' safety and performance specifications has given rise to a number of research projects and robot evaluation facilities. The National Bureau of Standards and Selcom (see *Robotics Age*, June 1985, p. 38) have been joined in their verification efforts by **Underwriters Laboratories Inc.**, the **Robotic Industries Association**, the **Industrial Technology Institute**, and **Worcester Polytechnic Institute's** Manufacturing Engineering Applications Center.

UL is offering a testing service designed to establish its proposed Standard UL 1740, which covers robotic systems intended for indoor use in industrial applications including welding, paint spraying, assembly, parts transfer, inspection, die-casting, and deburring. The standard contains construction and performance requirements intended to reduce to a reasonable safety level hazards such as electrical shock, fire, and casualty. To evaluate the effects of voltage transients, defined electrical surges are imposed on a robot system's electrical input while the robot is under normal operation. An abnormal test is used to determine the effects of power loss and restoration. The robot is also given an overload test in which an arm/payload combination exceeding design qualifications is moved through its designated work envelope.

Component evaluations are also performed on electronic safety circuits such as the speed-reduction circuitry and other motion controls, and object presence detectors. Robotic systems intended for use in locations defined as hazardous by the National Electrical Code must already comply with UL 913, the Standard for Intrinsically Safe Apparatus and Associated Apparatus.

The RIA has also been drawing up the first proposed American National Robot Safety Standard and will present the proposal at a seminar to be held in conjunction with Robots 10 in April. The standard, expected to receive official approval from the American National Standards Institute, outlines steps for the safe construction, installation, care, and operation of industrial robots and robot systems.

The Industrial Technology Institute, a not-for-profit corporation established to improve American industrial productivity and competitiveness, has for some time made available to its clients a variety of services in automated manufacturing technologies. ITI recently established a Robotic Evaluation Center (REC) in Ann Arbor, Michigan to provide robotic performance evaluation, application consulting and engineering, R&D, and training. Using Selcom's SELSPINE Robot Check System, REC conducts a set of standard evalua-

In The Robotics Age™

tion tests: point-to-point, including repeatability, cycle time/velocity, maximum velocity (slew rate), settling time/overshoot/undershoot, and hysteresis; continuous path, including circular interpolation, linear interpolation and cornering capability, and accuracy; and, finally, tests of cycle time and duty cycle. Customized evaluations can also be developed, such as specific application evaluations, detailed robot characteristics, and safety tests.

In a report from Worcester (Massachusetts) Polytech's Manufacturing Engineering Applications Center, Ulrich Griebel and Richard A. Higger note that "most state-of-the-art [robotic] position measuring systems will determine deviations in discrete locations, e.g., at the end of a programmed path, but will not provide any information about how this

position was reached." The researchers have devised a measurement system that uses five linear proximity sensors and one optical sensor incorporated in a measuring head that is attached to the robot arm. Six independent coordinates can be monitored in reference to a fixed steel gauge during the robot's travel. Maximum linear travel on the system used for the project is 39.4 in., maximum travel speed is 39.4 in./sec., and the resolution of a single sensor is better than 0.0004 in. The analog sensor outputs are converted to digital values via a data acquisition board and are transferred to a microcomputer for data analysis, display, and storage. The system has been designed for adaptability to almost any robot currently available on the market.

MARKET RESEARCH

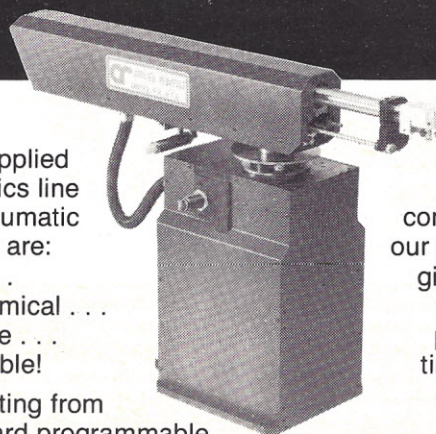
Figures released by the **Robotic Industries Association** at its annual meeting in January indicate that shipments by U.S.-based industrial robot suppliers rose by 81 percent in dollar value and by 34 percent in units in the third quarter of 1985 over the same period in 1984. A total of 1789 units, valued at \$156.9 million were shipped, compared with 1336 at \$86.9 million in the comparable quarter of 1984. In the third reporting quarter of 1985, total shipments were 4553 at \$299.8 mil-

lion; 1984's third-quarter report set the number at 3633 units at \$234.9 million. New orders also showed significant rises, up 71 percent in dollar value and 33 percent in units, with an order total of 1636 units valued at \$117.6, up from 1260 at \$75.7 million. Unfilled orders were 2591 at \$374.6 million for the first three quarters of 1985, up from 1984's 1578 at \$131.1 million. The RIA estimates that more than 20,000 robots are now in use in the U.S. The organization also announced

The Bottom Line Is... Your Robot System Has To Be Profitable!

The Applied Robotics line of pneumatic robots are:
fast . . .
economical . . .
reliable . . .
profitable!

Operating from
standard programmable



controllers,
our systems
give a 2-6
month
payback
time after
time!

... and that's the Bottom Line.
APPLIED ROBOTICS

10 Northern Blvd., Amherst, N.H. 03031
(603) 883-9706

See us at Robots 10, booth #2012

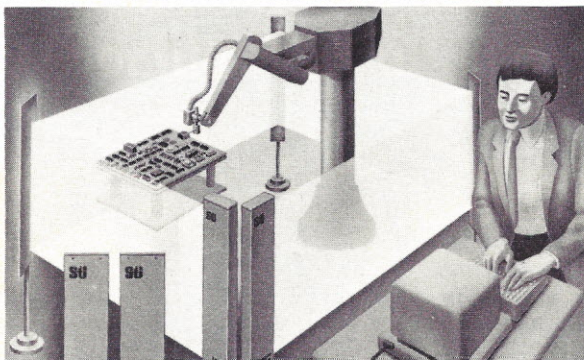
Advertising

R.S. No.	Company
30	ADEC, p. 4
31	AEG Corporation, Cov. II
32	Adept Technology, Inc., Cov. IV
33	Alpha Products, p. 32
34	Amatrol, Inc., p.31
35	American Grinding & Machine Co., p. 28
36	American Institute of Aeronautics & Astronautics, Inc., p. 29
37	Ampro Computers, Inc., p. 43
38	Applied Robotics, Co., p. 35
39	Scientific Technology Inc., p. 36
41	BEI Industrial Encoder Div., p. 17
40	Bersearch Information Service, p. 35
42	Coret & Company, Ltd., p. 24
43	CyberPak Co., p. 39
44	Dorner Mfg. Co., p. 37
45	E.J. Krause & Associates, Inc., p. 11
46	Gelzer Systems, Co., p. 25
47	Kustem Data Services, Inc., p. 36
48	Laboratory Microsystems, Inc., p. 34
49	Mecanotron Corp., p. 38
50	MillerEdge, p. 4
51	Motion Control Devices, Inc., p. 37
52	Polaroid Corp., p. 21
53	Rechner Electronics Industries, Inc., p. 2
54	Rhino Robots, Inc., p. 42
55	Vision '86, p. 33
56	Robotic Systems International, Ltd., p. 39
57,58	1986 Sensor & Transducer Directory, Cov. III
59	Sensors Expo, pp. 22,23
60	Springer-Verlag New York, Inc., p. 15
61	Tychoway Bearings Co., p. 3
62	VSI Automation Assembly, p. 10
63	Vernitech, p. 38
64	Vernitron Controls, p. 43
	Weldun International, p. 5

* Correspond directly with company

OPTOSAFE™

PUT STI'S LIGHTS ON FOR SAFETY



STI's new light curtain is a fourth generation, totally solid-state system. The Model P4000's special self-checking circuitry constantly monitors the system for component failures. Designed to meet or exceed OSHA and ANSI standards.

Patented circuitry automatically compensates for ambient light and particulates such as dust and fog. Field programmability and external computer control are optionally available for automatic machine tool applications.

This safety curtain has been specified by many of the most discriminating and major U.S. auto, electronic and computer manufacturers.

For more information, contact any STI distributor or the factory.

Distributor Inquiries Invited

800 221-7060

Sti®

1201 San Antonio Rd./Mountain View/CA 94043

415 965-0910

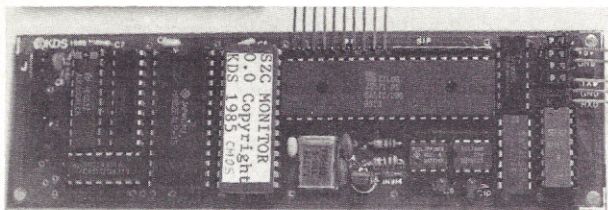
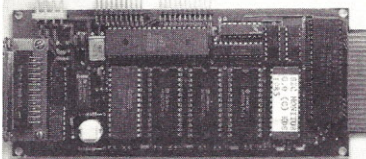
See us at ROBOTS 10, Booth #3019

© 1985 Scientific Technology Incorporated. All rights reserved.

TWO Z8 BASED CONTROLLERS

SLIM Z8 Controller

Packed on a 3" x 6.75" PC board the SLIM Z8 Controller offers 40K jumper-selectable memories of any combination of CMOS RAMs, EPROMs, or EEPROMs. With Zilog Z8671 CPU on board and one 8255 chip the controller has 38 I/O programmable lines to interface with the outside world. The EEPROM can be easily programmed at 5V with TINY BASIC command. The RS232 port and on-board simple monitor make SZC an ideal development tool and a dedicated controller. \$175



TINY Z8 Controller with 8 Channel A/D Converter

Tightly packed on a 1.7" x 6" PC board the Z8671 based controller offers a jumper-selectable 8K to 32K RAM, EPROM, and EEPROM combination of memories. In addition to 8 programmable I/O lines and a RS232 serial port the controller has 8 channel A/D converter with a choice of 8 or 10 bit resolutions. Along with on-chip BASIC the product is ideal for dedicated control and data acquisition. Power requirement is 5 Volts only.

Other common features for the two products include two counter/timer, 7 baud rates, and 6 interrupts. Forth supported.

Kustem Data Services, Inc.

PO Box 734, Franklin Park, NJ 08823 201-297-5369

In The Robotics Age™

that it would move from Dearborn to new headquarters in Ann Arbor, Michigan. The relocation is expected to be complete by February 28.

A new report from **The Freedonia Group** of Columbus, Ohio predicts that U.S. sales of robots will increase over 20 percent/year and reach \$3.25 billion by 1995, with an installed base of 109,000. The report goes on, however, to identify existing and anticipated snags in the growth picture. Despite the "great promise" of GMF's Manufacturing Automation Protocol, an industry-wide communications standard has yet to be established. The incorporation of robots requires that the factories, the production processes, and even the parts used must be adapted to the robot, a potentially costly changeover in terms of product redesign, new tooling and fixturing, changes in plant layout, and software development. Further, the projected growth rate is lower than the forecasts of the past several years and well below the historical growth of 40 percent. On the brighter side, resistance on the part of workers, previously expected to present a significant barrier, has not greatly inhibited the adoption of robotics, the report continues. Sizable opportunities exist for arc welding, palletizing, machine loading, assembly (especially small-parts), and inspection robots. Parts and attachments will become important as the installed base expands and as a replacement market emerges. Spot welding, parts transfer, and parts finishing robots will experience more subdued growth (about 12 percent/year) because these robots

have reached a more advanced degree of market maturity. Although prices of many electronic components and subassemblies are declining, many other parts going into robots are rising in cost, leading to an anticipated rise in average robotic unit prices of over 4 percent/year. While U.S. suppliers are retaining their competitive advantages in technology, quality, availability of equipment and spare parts, and marketing and technical service support, they are unable to compete on price and maintenance costs. Foreign suppliers will continue to strengthen their foothold in the U.S. market, and by 1995 a net import position of \$225 million (about 7 percent of sales) can be expected. Joint ventures between U.S. and foreign (mainly Japanese) robot suppliers will grow in importance. The robotics industry has experienced a shake-out and is now composed of about 75 companies, of which only about 45 provide complete robotic systems. The rest supply parts and attachments and other peripherals. Robotic suppliers are beginning to incorporate a systems approach that is more adaptive to end user needs. Successful competitive strategies include product differentiation via technological exclusivity and market segmentation along robot type or end user lines. The factory automation companies will have the financial, technical, and marketing resources to provide a complete application package to the end user, the report concludes, and the smaller firms will find market niches or will service the larger firms and the factory automation consultants.

In The Robotics Age™

BOOK REVIEWS

Introduction to Robotics, Mechanics and Control. By John J. Craig. 300 pages. Addison-Wesley. 1986. \$36.95.

The preface of this book is good, accurately outlining the work to be developed in mechanical manipulation, discussing the background requirements for students to use the book, and explaining briefly the contents, chapter by chapter. Unfortunately, the publisher's flyleaf is overblown—"Until now, good teaching material for this emerging technology [robotics] was lacking. Here at last..." The first part of this quotation may be correct; the second is not.

I have an aversion to photographs in books when they add no useful information and act only as fillers. The subject of Craig's book is so vast that he could have used space in this 300-page book more advantageously.

The initial specification of robot joints is imprecise, incomplete, and potentially ambiguous, in spite of the accompanying diagrams. What is a prismatic joint? Not all types of robotic joints are considered. This lack of definition infects that description of joint space and Cartesian space, and manipulator dynamics. The *lead-up* to the specification of rotation matrices is fine as far as it goes, but the reader is left to infer the matrix

$$\begin{bmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

a result developed by Richard Paul [*Robot Manipulators*, MIT

Press, 1981], before considering an example of its use. One of the failings of Paul is that he tends to plunk underived formulas on the reader's lap. Craig, who derives much of his inspiration from Paul, inherits this trait.

The kinematic analysis of some commercial robots is useful material. The references given are appropriate, but scarce—more are needed. The definition of solvability for the inverse kinematic solution of a robot is troublesome, since all robots are solvable. Craig is not correct when he states that "only in special cases may robots with six degrees of freedom be solved analytically."

Craig's definitions of dextrous and reachable workspace are very useful guides in path planning. The trajectory planning chapter, too, is interesting, and it would have been nice to see more of this. Unfortunately, this book is a series of samplers with too little information on each to satisfy, so to base a college course on this text would be difficult.

It is probably unfair to expect an introductory book to include a significant amount of new material. Eighty percent of robotics books are at the gee-whiz, popular level. This book lies in the other 20 percent. It could be useful for someone with an analytical, science-based background just entering the field of robotics. But for those of us with a small library of robotics references, the book does not contain enough new information to warrant its expense.

Robert E. Parkin, Ph.D.

Robot Feeders

You can now match the ultra efficiency of robotic equipment in your manufacturing or assembly operations with *programmable low profile conveyors* to provide precision movement of parts to and from automated stations. Dorner engineers have designed state-of-the-art systems for some of the nation's leading manufacturers.

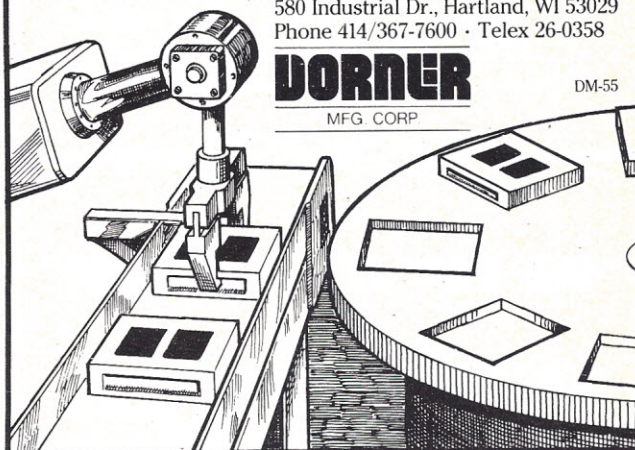
Send for our 'Idea Starter' catalog on custom systems

580 Industrial Dr., Hartland, WI 53029
Phone 414/367-7600 • Telex 26-0358

DORNER

MFG. CORP.

DM-55



QUICK-MOUNT MODULAR ENCODERS



OEMs. Now you can save space, get high performance, and avoid assembly headaches with MCD's **NEW** Modular Encoders. All components are pre-aligned for fast, simple and trouble-free direct mounting on your motor shaft.

M15

- ☐ 1/4 to 3/8" shafts
- ☐ Square wave output
- ☐ Up to 1000 PPR

- ☐ Wire or ribbon cable terminations
- ☐ Differential line driver output option
- ☐ 18 month warranty

M21

- ☐ 1/4 to 5/8" shafts
- ☐ Square or sine wave
- ☐ Up to 1200 PPR

MCD's Quick-Mount modular encoders offer a low profile with low inertia and cost-effectiveness. No assembly and alignment problems commonly associated with kit encoders. Call or write for complete specifications today.

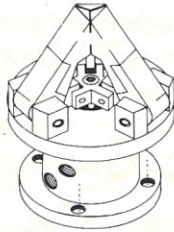
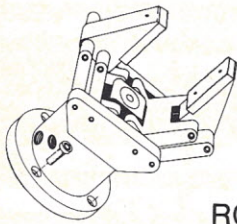
New Dimensions in Motion Control



Motion Control Devices, Inc.
80 Stedman St., Lowell, MA 01851
(617) 454-3407

MECANOTRON™

**YOUR SINGLE SOURCE FOR QUICK
CHANGE SYSTEMS & END OF ARM TOOLING**



**ROBOTIC PERIPHERALS
END EFFECTORS, ACTUATORS
END EFFECTOR CONTROLLERS
QUICK CHANGE TOOLING SYSTEMS**

SENSOR READY

WE PUT IT TOGETHER

MECANOTRON™ CORPORATION

1728 North Second Street, Minneapolis, MN 55411 (612) 521-8559
See us at ROBOTS 10, Booth #5033

KIT ENCODERS THAT REALLY SAVE YOU MONEY.

Most kit encoders are so tricky to align that they end up costing you more in labor than they save.

Not so Vernitech kit encoders.

Our special design comes with alignment tools and a simple set of instructions. It is so easy for *anybody* to assemble perfectly. The original low cost of our encoder plus the reduced cost of your "in-house" assembly will result in greatly reduced total cost. Buying Vernitech kit encoders can save as much as 50%!



Call or write

VERNITECH

a division of Vernitron Corporation

300 Marcus Boulevard, Deer Park, N.Y. 11729
(516) 586-5100 / TWX 510-227-6079

In The Robotics Age™

Robot Hands and Mechanics of Manipulation. By Matthew T. Mason and J. Kenneth Salisbury, Jr. 298 pages. MIT Press. 1985. \$30.00.

Books in the MIT Press series in artificial intelligence never lack information, and Mason and Salisbury's work is no exception. As always, it is clear that any author in this series has performed the work, achieved the results, and become the expert.

I applauded Salisbury's statement in the first chapter: "In performing the kinematic analysis our approach has not been to survey desirable human functions and try to emulate them. Rather we have taken a more abstract kinematic viewpoint."

In this work, the photographs are informative and appropriate. Diagrams of the mechanism of the Stanford hand are followed by photographs clearly showing the gripping action of the hand. The sizing of figures containing the same amount of information varies from very small to jumbo. One has the impression that MIT Press rushes a manuscript through with less regard for graphics than other publishers, but this permits a work to hit the streets faster, and so

is beneficial overall. Some of the penalties paid by the reader are diagrams not on the same page as the corresponding text, and poor editing (Figure 2 on page 114 is the same as Figure 3.1, and diagrams on pages 29, 115, and 155 are the same).

The work uses references appropriately and extensively, reinforcing the impression of scholarship. Occasionally, the research nature of the material makes it more like a paper in a technical journal than a book. For example, the Pluecker line is used without definition (but properly referenced) on page 16, leaving the uninitiated reader scrambling for cover. This work is not a textbook, and as such will probably not be adopted in college courses: it is a monograph that will be required reading for all who are engaged in the analysis and design of noncompliant robot hands.

It is interesting to note that the more advanced books in robotics demonstrate how little we know about robotics. Trivial books imply that we can do almost anything. Mason and Salisbury prove how little we know and how much more work there is to do. Take heart, budding researchers: here is lifelong job security. REP

CALL FOR PAPERS

The **IEEE Computer Society** will sponsor an international conference on computer aided design the week of November 10-15 in Santa Clara, California. Topics to be addressed include design synthesis, CAD systems, interactive graphics, modeling and simulation techniques, design automation, ex-

pert systems, layout and layout verification, testing, and hardware accessories. The due date for abstracts is May 9, 1986. Papers should be submitted to ICCAD-86 Secretary, AT&T Bell Laboratories, 1247 S. Cedar Crest Blvd., Allentown, PA 18103, telephone (215) 770-3485.

In The Robotics Age™

PEOPLE

► **Clifford R. Meyer**, president of **Cincinnati Milacron**, retired on December 31, 1985, for health reasons. He had been with the company since 1956, filling positions of steadily increasing management responsibility before being named president and CEO in 1982. Meyer's duties have been assumed by **Donald G. Shively**, who joined the firm in 1957 and was made executive vice president-operations in November, 1985.

► **Philip E. London** has joined **Cognition, Inc.** as vice presi-

dent of expert systems and company founder. Dr. London, who holds a Ph.D. in computer science, joins an existing team of nine cognition founders led by Philippe Villers, company president. He was previously associated with Teknowledge, Inc.

► **Peter Chiasson** has been named president and CEO of **Alsys, Inc.** He will also serve on the board of directors of both Alslys and its parent company, Alslys S.A. of France. Chiasson was formerly with the Electronics Division of Computervision Corp.

CORPORATE NEWS

► **Allen-Bradley** has adopted **Karel**, developed by **GMF Robotics**, as the standard application language for programming A-B's new robotic control products for industrial automation systems. (For more about Karel, see *Robotics Age*, September 1985, p. 10).

► **GMF Robotics** has announced what the firm terms an industry first—using robots to produce robots. The new Computer Integrated, Flexible Manufacturing System will be used to manufacture GMF's P-150 electric painting robots, which have developed a \$60 million backlog since their introduction last June. The new system is scheduled to go into operation early next year at GMF's technological development center, currently under construction in Rochester Hills, Michigan.

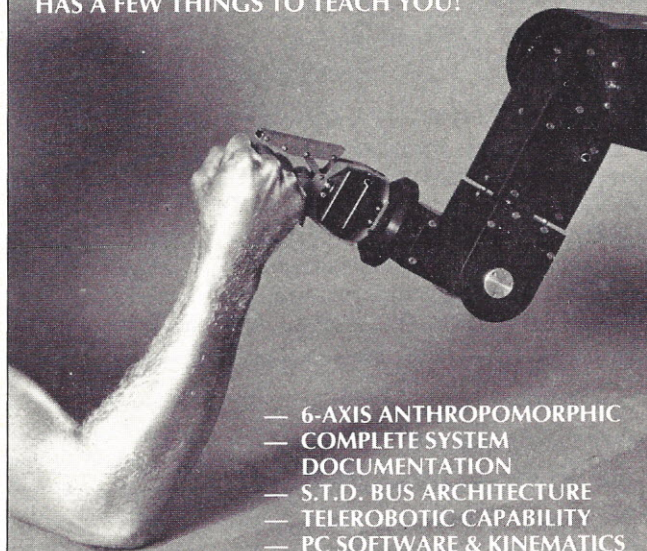
► **Advanced Assembly Automation, Inc.** has merged with **Fabrication Specialties Company**. The FABSPEC line of robotic positioning equipment will be manufactured in Advanced's facility. An additional \$1 million in equity has been infused for a minority interest in the corporation.

► **IBM and Industrial Networking, Inc.** have entered into an agreement to jointly develop MAP products. INI, a joint venture company between Ungermann-Bass, Inc. and GE, was the first Local Area Network manufacturer to offer board-level interfaces capable of supporting the entire MAP specification. According to INI president and CEO Joseph P. Schoendorf, initial development efforts will be focused on the industrial computer family.

ROBOTIC EDUCATION AND RESEARCH

EXCALIBUR

HAS A FEW THINGS TO TEACH YOU!



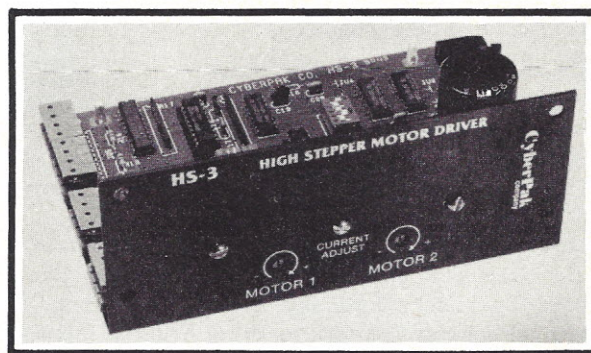
- 6-AXIS ANTHROPOMORPHIC
- COMPLETE SYSTEM
- DOCUMENTATION
- S.T.D. BUS ARCHITECTURE
- TELEROBOTIC CAPABILITY
- PC SOFTWARE & KINEMATICS



ROBOT 10 BOOTH 4050

ROBOTIC SYSTEMS INTERNATIONAL LTD. (604) 656-0101 TELEX: 049-7292
9865 W. SAANICH, SIDNEY, B.C. CANADA

16 Axis Step Motor Control Performance/Cost Break-Through



Cyberpak's BIPOLAR CHOPPER technology provides 2-5 times the performance of simple circuits. No external power resistors are required.

Complete 4 axis systems w/IBM-PC interface, including control system software (RBCS BASIC), at under \$1000. Driver modules start at \$89.50/axis.

CyberPak
company

P.O. BOX 38 ■ BROOKFIELD, IL 60513 ■ 312/387-0802

MC/VISA

OEM and Distributor Pricing Available

New Products

Winchester Disk Drive Option Is Available for CIM Operations

A 10-Mbyte Winchester disk drive option from GCA can store and access large numbers of programs and data files in the firm's CIMROC® 2 robot controllers and the CIMCON™ controllers and CIMPREP™ workstations. The drive is shock-mounted inside the controllers during field installation. A floppy-disk drive option is required before the Win-

chester drive can be installed; the floppy drive option package includes a 308-Kbyte drive with locatable drive door, file handler software, and five 3.5 in. diskettes. The disk file handler software accesses either drive, and the floppy drive can be used to archive programs from the hard disk.

For more information, contact: Elan Long, GCA/Industrial Systems Group, One Energy Center, Naperville, IL 60566, telephone (312) 369-2110. Circle 100

Four-headed Dispensing Robot Lays Two Different Materials

The QuadraSpenser™ is said to be the world's first automated dispensing system; it is capable of applying two different materials at 1200 in./min. in two different complex patterns. Developed by Robotics, Inc., the system is based on a Cartesian coordinate robot with Allen Bradley Series 8200 controllers. The QuadraSpenser is gantry-mounted and has a 10 by 11 ft footprint.

Currently in use at two automotive stamping plants, the system uses two of its heads to lay a structural bonding material around the perimeter of a car hatch gate and the other two to apply an anti-flutter/sound-deadening mastic in a dash pattern to the interior contact points between the hatch gate's inner and outer panels. The bead path totals nearly 350 in., and the cycle is completed in 8 sec. Repeatability is ± 0.010 in.

For more information, contact: Robotics, Inc., R.D. 3, Rte. 9, Ballston Spa, NY 12020, telephone (518) 899-4211. Circle 101

Power Cell Incorporates Hall-effect Transducers

Hall-effect transducers in Load Controls' new power cell sense variable frequency, fixed frequency, and DC power. Outputs available are 4-20 mA, 0-1 mA, 0-5 V, and 0-10 V. The output is linear and electrically isolated. The power signal can be used as an input to computers or programmable controllers. It can drive meters, displays, and chart recorders. The power cell can also be connected to LCI load controls for machine or pro-



cess control. Capacity can be changed in the field to match the load and to maximize sensitivity.

For more information, contact: William H. McClurg, Load Controls, Incorporated, Technology Park, 10 Picker Rd., Sturbridge, MA 01566, telephone (617) 347-2606. Circle 102

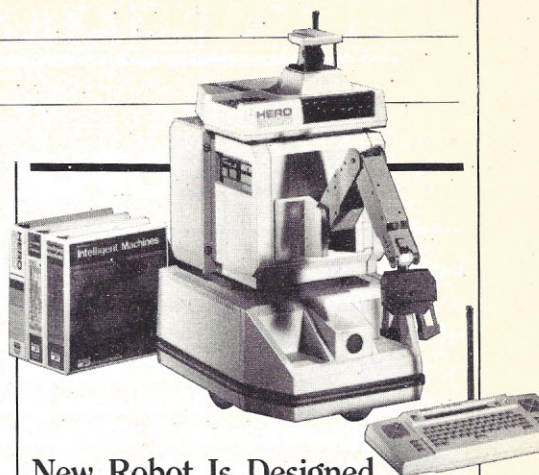
Laser Probe System Is Designed for End Effector Mounting

A miniature noncontact laser probe designed to measure parts to an accuracy of ± 0.0005 in. is available from Candid Logic. The Mini-Precimeter weighs 4.75 oz. and measures 3 by 2 by 5/8 in. It combines a laser beam and a triangulation principle to determine the precise position of virtually any working surface at a standoff distance of 3.5 in. It has a



measuring range of 1.25 in.

Designed for use on robotic end effectors and



New Robot Is Designed for Industrial Training

The newest addition to Heath's robots, the HERO 2000, is said to simulate virtually every automation process currently in industrial use. The educational package covers the concepts of robotics, process control, factory automation, CAD/CAM, and computer-machine interfacing. Three courses of instruction are available for use with the robot.

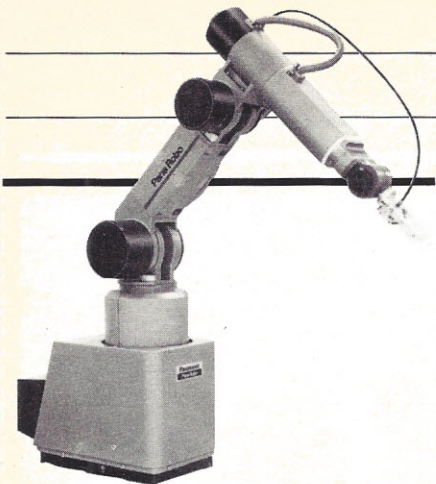
HERO 2000 is 32 in. tall and weighs 78 lb., including the arm. All operating systems are controlled by a 16-bit master processor. The robot's drive, and torso and arm movement are powered by eight closed-loop DC servomotors. Eleven 8-bit slave microprocessors under master processor control permit simultaneous I/O functions. On-board ROM is 64 K and includes a specially enhanced BASIC as well as demonstration programs, direct text-to-speech conversion, and diagnostic routines. With optional accessory boards, on-board RAM can be expanded from 24 K to over 1/2 MByte. Other features include a remote console with an RF link that permits control and programming from up to 100 ft away and two sonar transducers that sense objects and movement up to 10 ft away. The head-mounted sonar unit scans 360 degrees, while the base unit points straight ahead.

For more information, contact: Heath Company, Department 570-506, St. Joseph, MI 49085, telephone (616) 982-3210. Circle 103

CMMs, the system allows for location, dimensional measurement, and qualification of complex parts without distortion. The unit measures metal parts and also soft or fragile items such as rubber, clay, and liquids. In addition to the Mini-Precimeter, the system includes a power supply and a microprocessor control unit for signal processing.

For more information, contact: Candid Logic, Inc., 31681 Dequindre, PO Box 71943, Madison Heights, MI 48071-0943, telephone (313) 583-9266. Circle 104

New Products



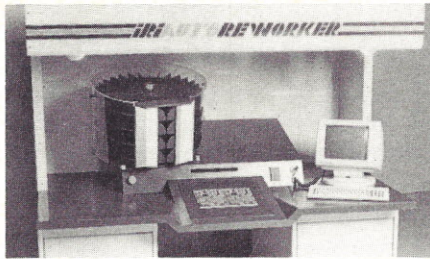
Plastic Processors Are Offered Full Robotic Systems Integration

Application Automation (an AEC company) has added the Panasonic line of robot systems to offer post-molding assembly, inspection, and packaging functions, as well as automated parts removal to plastics manufacturers. The robots move at up to 126 in./sec. under microprocessor control to perform complex fastening, component insertion, coating, and part-orientation tasks. They can accept user-specified quick-change end-of-arm tooling. Optional RS-232 communications permit interface to PCs or other controllers. A sequence module is available that supports system expansion to CIM.

The robots range from 2-axis pick-and-place to 6-axis, vertically integrated units. Reach is up to 20 in.; swing up to 270 degrees; adjustable velocity control, repeatable closed loop servopositioning accuracy up to ± 0.002 in., and load capacity to 11 lb. Control system features include teach mode, digital timing functions, internal IC memory with battery backup for storing up to 1000 program steps, and up to 10 inputs and 11 outputs.

For more information, contact: Application Automation, 850 Pratt Blvd., Elk Grove Village, IL 60007, telephone (312) 593-5000.

Circle 105



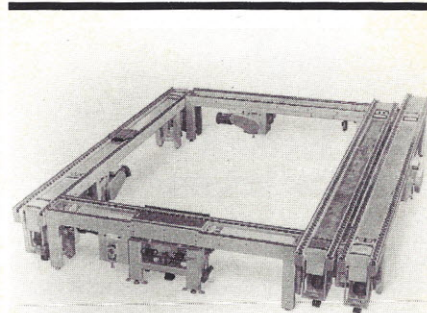
Workcell Series Is Designed for Electronics Manufacturers

The Inspector Workcell Series from IRI is designed for the electronics/electrical manufacturing process. Its modules, which can be user-specified, are: the Auto Inspector, providing SMD, through-hole, OCR, post-solder, and bare-board inspection; the Auto Reworker (shown), with a database link, providing a board repair station with calibration, parts presentation, laser guidance, vision verification, and board identification; the Auto Trainer, providing online/offline, boards/parts, CAD, and manual training and editing; the Auto Handler, providing materials handling, inspector loading/unloading, and robot routing; the Auto Supervisor/Reporter, providing management reports that include part/board error analysis, product tracking, report generation, job/order status, and part purging; and the Auto Networker, providing computer/network communications to CAD/CAM databases, accounting data, materials planning, production planning, and quality control information.

The products can be configured to specific applications by using fixed and/or moving lights and cameras, multiple vision systems, multiple processors, and robotic controllers.

For more information, contact: Chuck Giordanella, International Robomation/Intelligence, 2281 Las Palmas Dr., Carlsbad, CA 92008, telephone (619) 438-4424.

Circle 106



Transporter System Adapts to Individual System Requirements

The ACCU-Wheelveyor Transporter from I.T. Equipment is an open-centered, non-synchronous, linear, assembly conveyor system with modular design and programmable sequences that allow standardized trays or pallets to be moved along a controlled path. The device can be interfaced with robots, storage/retrieval systems, AGVs, and other automated machinery. Various sizes of power and free chain are available to suit load conditions and sizes.

Open center dimensions and individual conveyor lengths are flexible to adapt to individual system requirements. Center drives eliminate restrictions caused by end drive locations. The open center provides central access to the unit load; workstations, right-angle transfers, positioning devices, turn tables, and other devices offered as accessories can be fitted into the basic transporter lines. Drives, pneumatic components, and controls are available in various domestic brands to meet client requirements.

For more information, contact: George A. Avon, Jr., VP Marketing, I.T. Equipment, Inc., 1147 Mishawaka Ave., South Bend, IN 46615, telephone (219) 282-2381.

Circle 107

Pressure Switches Are Suitable for Pressure and Vacuum Sensing

The 890-0010 series of pressure switches from Robitech are said to eliminate the need for two different switches for either positive or negative pressure-sensing applications. The switches employ a sealed metal bellows pressure sensor that is not subject to the temperature sensitivity, sticking, or wear associated with sliding piston switches. A Phillips head screw provides trip point setting



with greater than 1 percent FS repeatability, from 0-90 psi or up to 28 in. HG. The O ringed

10-32 NF male thread port connection makes a positive seal and can be adapted to 1/8 in. standard pipe for system retrofitting.

The internal SPDT snap action switch is rated for 5 A, 115 VAC, or up to 28 VDC. A 0.1 in. spaced, prewired amp type connector permits plug-on jumper connection. Applications include robotic process control and factory automation.

For more information, contact: Philip Surette, Robitech, Inc., 10 Upton Dr., Wilmington, MA 01887, telephone (617) 657-6143.

Circle 108



Robotic Workcell Is Designed for Industrial Training

A new addition to the Rhino XR Series of robotic training systems is the FG1331, a workcell that integrates the Rhino robot with the following accessories: XR Series robotic arm, Mark III controller, teach pendant, RoboTalk software, linear slide base, rotary carousel, belt conveyor, workcell order center, vertical conveyor, ball sorter, inspection station, pallet return ramp, base, base support, and mounting accessories.

The height of the workcell is 40 in., and its floor space requirement is 42 in. It runs on 120/240 VAC, 775 watts, 50/60 Hz. A comprehensive manual is included, as well as manuals for each main component.

For more information, contact: Rhino Robots, Inc., 3402 N. Mattis Ave., Champaign, IL 61820, telephone (217) 352-8485.

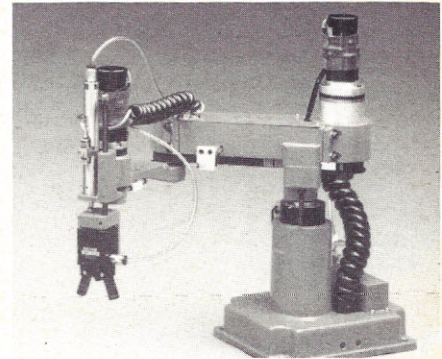
Circle 109

New Products

Servo Robot Performs High-Speed Parts Handling

A SCARA DC servo robot available from ATP, Inc. is said to offer high-speed parts handling at a lower price than other robots with the same capabilities. The 88-4SR is designed for assembly and electronic component insertion. Its three DC servos with digital optical encoders and harmonic drive reducers offer position repeatability and accuracy up to ± 0.0004 in. The robot has a reach of 12 in. and moves at combined speeds of 32 in./sec. It can be equipped with an optical 8 in. or 16 in. horizontal running unit to increase its work envelope.

The 88-4SR features a 6-program storage capacity, with 78 set points each, to provide up to 468 total set points. An RS-232 interface allows linking of a host computer for unlimited program capacity, loading, editing, and saving. A sequencer interface for I/Os allows access through the user's programmable controller. Other optional accessories include air and vacuum end effectors and software for PCs.



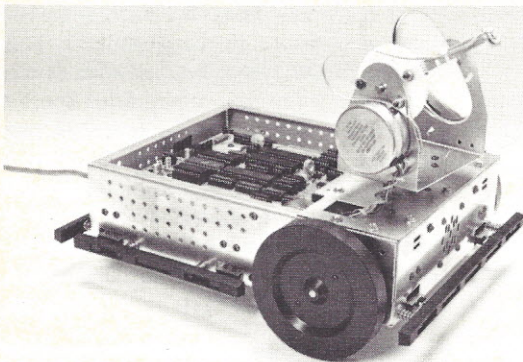
For more information, contact: ATP, Inc., 2451 Baseline Rd., Grand Island, NY 14072, telephone (716) 773-0972.

Circle 110

Robotic System Can Kit Wires

Gelzer's new Model RWP (Robotic Wire Prep) prepares and kits wires in sequence for cable harnesses and complex jumper and connector sets. Designed primarily for small lot

SPECIAL OFFER: SCORPION MOBILE ROBOT KIT



World leaders in instructional robotics

RHINO

R O B O T S

3402 N. Mattis Ave.
P.O. Box 4010
Champaign, IL 61820
(217) 352-8485

Originally \$660

NOW ONLY \$299*

SAVE OVER 50%

FACTORY
DIRECT
ONLY

The package price gives you the Scorpion kit with everything needed for assembly plus our 250-page assembly and operation manual (a \$20 value) as a free bonus.

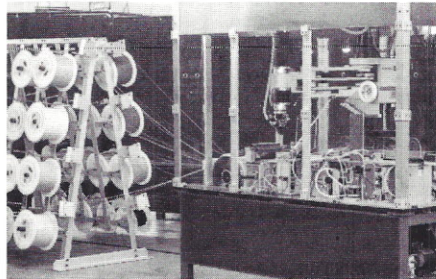
The Scorpion is a versatile floor mobile robot that can be run from the RS-232C port of any computer, small or large. It is designed specifically for the serious robotic enthusiast who owns a personal computer and would like to experiment with robotics, artificial intelligence, machine intelligence, pattern recognition, and mobile robot theory. These activities are permitted by the Scorpion by virtue of its unique features, which include 2 drive motors, 4 bumpers with 2 micro-switches each, 2 programmable eyes, a speaker with tone and duration programmability, a 2 axis optical scanner that allows patterns of the brightness of the robot's environment to be displayed on the CRT of the computer, and a 2 phase floor scanner that can be used to allow the Scorpion to track the floor environment in an intelligent manner.

Enclose check or money order with order. VISA or Mastercard charges accepted. *Power supply not included. Shipping extra.

New Products

applications, the robot can produce a tape of finished wires that have been cut to length, stripped, tinned, and terminated.

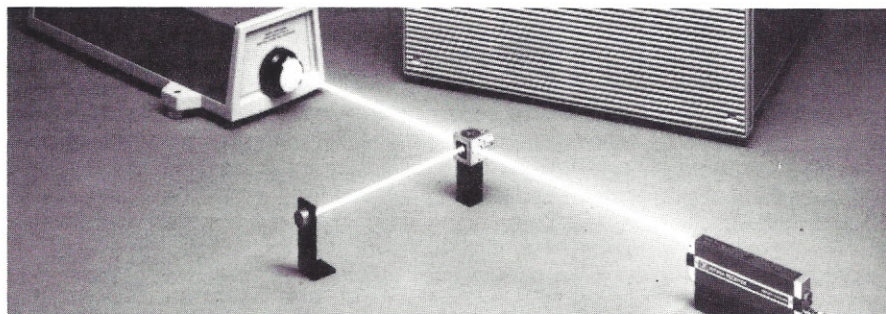
The current model accesses 40 wires of different gauges and colors, selecting the right wire in sequence, pulling it to the correct length, and capturing and cutting the other end—using only one gripper. The wire is then taped with the free ends on one side of the tape,



which then advances through multiple stations for stripping, tinning, and terminating prior to the final packing operation.

For more information, contact: Gelzer Systems Company, 4199 Weaver Ct. South, Hilliard, OH 43026, telephone (614) 771-0117.

Circle 111



Laser System Improves Monitoring of Precision Equipment

A new laser position transducer from Hewlett-Packard, the HP 5527A, is said to improve submicron position control and monitoring of precision equipment. The system consists of five modular components: a laser head that features a 2-frequency design and allows several axes of measurement; measurement optics that consist of an interferometer and a reflector that generate optical-measurement information when motion occurs between

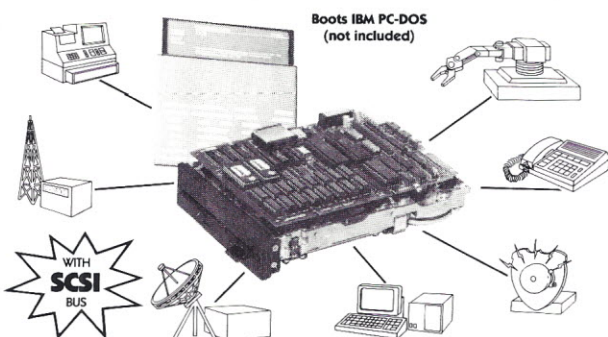
them; splitting and bending optics that divide and direct the laser beam for multiple-measurement axes and various measurement configurations; optical receivers that translate the optical-measurement signal into an equivalent electrical signal; and new electronics that provide position information for position monitoring and feedback.

The system can resolve linear-position measurements of 4 nm at velocities of up to 40.6 cm/sec. Control for closed-loop systems is a 1.5 MHz position or position-error update rate. Accuracy is 0.1 ppm (in a vacuum).

Continued on page 44

Little Board™/186....\$495

High Performance, Low Cost PC-DOS Engine



- Three times the COMPUTING POWER of a PC
- Data and File Compatible with IBM PC, runs "MS-DOS generic" programs
- 8 MHz 80186 CPU, DMA, Counter/Timers, 128/512K RAM, zero wait states, 16-128K EPROM
- Mini/Micro Floppy Controller (1-4 Drives, Single/Double Density, 1-2 sided, 40/80 track)
- 2 RS232C Serial Ports (50-38, 400 baud), 1 Centronics Printer Port
- Only 5.75 x 7.75 inches, mounts directly to a 5-1/4" disk drive
- Power Requirement: +5VDC at 1.25A; +12VDC @ .05A; On board -12V converter
- Boots IBM PC-DOS (not included)
- SCSI/PLUS™ multi-master I/O expansion bus
- Software Included:
 - PC-DOS compatible ROM-BIOS boots DOS 2.x and 3.x
 - Hard Disk support
- OPTIONS:
 - Expansion board with:
 - 128 or 512K additional RAM
 - 2 Sync/Async RS232/422 serial ports
 - Battery backed Real Time Clock
 - 8087 Math Co-Processor
 - Buffered I/O Bus
 - STD Bus Adapter
 - Utilities source code
 - TurboDOS / Networking

AMPRO
COMPUTERS, INCORPORATED

IBM®, IBM Corp., 80186®, Intel, Corp., Turbo DOS®, Software 2000, Inc.

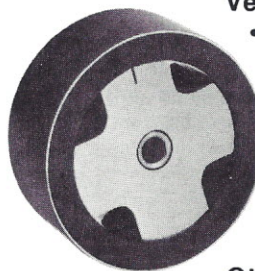
67 East Evelyn Ave. • Mountain View, CA 94041 • (415) 962-0230 • TELEX 4940302

VERNITORQ™

Limited Angle Brushless DC Torque Motors

Vernitorq motors feature:

- Direct drive
- 90% of max torque through 120°
- Infinite resolution
- Fast acceleration
- No cogging or ripple
- No electrical or mechanical noise
- 1" diameters and up



Other Vernitron products include:

- Torqsyn Remote Positioners
- Mil-Spec Synchros
- Pancake Synchros and Resolvers
- Indicator and Subsystem Assemblies



VERNITRON SAN DIEGO

A Division of Vernitron Corporation
1601 Precision Park Lane, San Diego, California 92073
(619) 428-5581, TWX: 910-322-1862
FAX (619) 428-5090

Classified Advertising

SYNTELLECT CORPORATION ANNOUNCES VIDEO COURSES ON ARTIFICIAL INTELLIGENCE, EXPERT SYSTEMS AND ROBOTICS. You have had the opportunity of reading Dr. Rajaram's articles in ROBOTICS ENGINEERING. The unique combination of his scholarship, practical experience and outstanding communication skills has made Dr. Rajaram one of the most highly sought lecturers and consultants in the fields of AI, Expert Systems and Robotics. This is now available to you, where you work, through a series of five video courses developed by him exclusively for SYNTELLECT. For more information, write to: SYNTELLECT Corporation, Educational Services Department, PO Box 580057, Nassau Bay, TX 77058. Telephone: (713) 482-6274. EDUCATIONAL AND NONPROFIT INSTITUTIONS SAVE OVER 50%.

ENGINEERS: WE HAVE YOUR NEXT POSITION! Numerous Design, Development, Research and Manufacturing positions available NATIONWIDE for degreed candidates with experience in any of the following areas: Robotics, Automated Systems, Control Systems, Artificial Intelligence, Hardware/Software. All fees company paid. Contact: JAMES E. IAN-
NONI & ASSOC., PO Box 128, Canterbury, CT 06331, (203) 546-9448.

New Products

Continued from page 43.

Repeatability is 0.02 ppm (in a vacuum).

User-friendly features include controllability, simplified servo-loop interfacing, extensive self-testing, self-configuring, and integral power-

supply standard.

For more information, contact: Inquiries Manager, Hewlett-Packard Company, 1820 Embarcadero Rd., Palo Alto, CA 94303.

Circle 112

LITERATURE

- *Keeping America At Work: Strategies For Employing The New Technologies.* Contact: Barbara Monteiro, John Wiley & Sons, 605 Third Ave., New York, NY 10158, telephone (212) 850-6497.
- *Synchro Conversion Handbook.* Contact: Marketing Dept., ILC Data Device Corporation, 105 Wilbur Place, Bohemia, NY 11716, telephone (516) 567-5600.
- *1985-86 Semiconductor Equipment and Material Institute's Membership Directory.* Contact: Marge Ryan, SEMI, Dept. 05607, San Francisco, CA 94139, telephone (415) 964-5111.
- *1986 Directory of Corporate Affiliations.* Contact: National Register Publishing Company, 3004 Glenview Rd., Wilmette, IL 60091, telephone (800) 323-4601; in Il-

linois, (312) 441-2210.

- *Patenting and Marketing Your Invention.* Contact: Helen Bashar, Van Nostrand Reinhold, 115 Fifth Ave., New York, NY 10003, telephone (212) 254-3232.
- *Klinger Catalog 584B.* Contact: Klinger Scientific Corp., 110-20 Jamaica Ave., Richmond Hill, NY 11418, telephone (718) 846-3700.
- *End of Arm Tooling: Tips and Techniques.* Contact: Science Media, PO Box 910, Boca Raton, FL 33432, telephone (305) 391-0332.
- *Airpax Circuit Breaker Handbook and Catalog.* Contact: Airpax Corporation, Cambridge Division, Woods Rd., Box 520, Cambridge, MD 21613, telephone (301) 228-4600.

Calendar

Continued from page 4.

21-24. **Artificial Intelligence/Knowledge-based Engineering Seminar.** Washington, DC. Contact: Conference Manager, U.S. Professional Development Institute, 1620 Elton Rd., Silver Spring, MD 20903, telephone (301) 445-4400. (To be repeated 5-8 May in Los Angeles, CA; 27-30 May in New York, NY; 16-19 June in Austin, TX; and 8-11 July in Chicago, IL.)

22-24. **Quality Expo TIME.** O'Hare Expo Center, Rosemont, IL. Contact: Quality Expo TIME, 2400 E. Devon Ave., Suite 205, Des Plaines, IL 60018, telephone (800) 323-5155; in IL, (312) 299-3131.

27-30. **Expert Systems.** Hyatt Regency, Cambridge, MA. Contact: Continuing Education Institute, 10889 Wilshire Blvd., Los Angeles, CA 90024, telephone (213)

824-9545. (To be repeated 5-7 May in Monterey, CA.)

28-30. **Speech Tech '86.** Waldorf-Astoria Hotel, New York, NY. Contact: Stanley Goldstein, Publisher, Media Dimensions, Inc., 42 E. 23rd St., New York, NY 10010, telephone (212) 533-7481/7483.

29-May 1. **Motor City Fluid Power Show V/National Conference on Fluid Power.** Cobo Hall, Detroit, MI. Contact: G.B. Randall, 4922 Wildwood, Harrison, MI 48625, telephone (517) 539-2745.

MAY

6-8. **Control Expo 86.** O'Hare Exposition Center, Rosemont, IL. Contact: Tower Conference Management Co., 331 W. Wesley St., Wheaton, IL 60187, telephone (312) 668-8100.

6-8. **Logistex 86.** Cervantes Convention Center, St. Louis, MO. Contact: Logistex 86, 940 Western Ave., Pittsburgh, PA 15233, telephone (412) 323-1808.

12-13. **UNIX Operating System Seminar.** Dallas, TX. Contact: Conference Manager, U.S. Professional Development Institute, 1620 Elton Rd., Silver Spring, MD 20903, telephone (301) 445-4400. (To be repeated 19-20 May in Boston, MA; 2-3 June in Washington, DC; 9-10 June in San Francisco, CA; 16-17 June in New York, NY; and 23-24 June in Chicago, IL.)

13-15. **Electro/86 High Technology Electronics Exhibition and Convention.** Bayside Exposition Center, World Trade Center, Boston, MA. Contact: J. Fossler, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045, telephone (213) 772-2965.

14-16. **C Programming Seminar.** Dallas, TX. Contact: Conference Manager, U.S. Professional Development Institute, 1620 Elton Rd., Silver Spring, MD 20903, telephone (301) 445-4400. (To be repeated 21-23 May in Boston, MA; 4-6 June in Washington, DC; 11-13 June in San Francisco, CA;

18-20 June in New York, NY; and 25-27 June in Chicago, IL.)

14-16. **Fiber Optics Technology for Communications.** Contact: Ron Donais, The George Washington University, Washington, DC 20052, telephone (202) 676-8523 or (800) 424-9773.

JUNE

5-6. **Second Annual Workshop on Robotics and Expert Systems/ROBEXS'86.** Gilruth Center NASA/Johnson Space Center, Houston, TX. Contact: Deborah A. Poor, Instrument Society of America, 67 Alexander Dr., PO Box 12277, Research Triangle Park, NC 27709, telephone (919) 549-8411.

17-18. **Robotic End Effectors: Design and Applications.** Detroit, MI. Contact: Diane M. Korona, Program Administrator, Special Programs Division, Robotics International of SME, One SME Dr., PO Box 930, Dearborn, MI 48121, telephone (313) 271-0039.

1,000 SENSOR PRODUCT SOURCES

The 1986 Sensor and Transducer Directory

Now you can locate nearly 1,000 suppliers of sensor and transducer products in a single publication. The 1986 *Sensor and Transducer Directory*, from the publishers of *Sensors* magazine, lists nearly 1,000 companies producing over 400 types of sensors and transducers.

The 1986 *Sensor and Transducer Directory* provides a comprehensive list of suppliers for each sensor category. Each company listing includes the company address, key personnel, and the sensor and transducer products available. For further information, an optional company/product line profile is also provided.

If you're looking for sensors, don't waste valuable time paging through catalogs and spec sheets. Join the thousands who have sensor sources at their fingertips—in the 1986 *Sensor and Transducer Directory*. Order yours today!

ONLY \$49.95

☐ Please send _____ copies of the 1986 *Sensor and Transducer Directory* at \$49.95 in the U.S., \$51.95* in Canada, or \$59.95* other foreign countries (includes postage and handling costs).

☐ Payment Enclosed \$ _____

☐ Personal Check

☐ Bill Me PO# _____

☐ MasterCard

☐ Visa

Expires _____

Account No. _____

Signature _____

Name _____

Company _____

Address _____

City _____

State _____

Zip _____

Phone _____

Send to **North American Technology** 174 Concord St., Peterborough, NH 03458 (603) 924-7261
*U.S. funds drawn on a U.S. bank

4/86 RE

Why robot vision doesn't have to slow a robot down.

Most robot vision systems simply aren't good communicators. They load a robot down with more data than it can handle... and transmit that data over slow serial or I/O ports. So while they might "see" in real time, they can't make the robot react in real time.

AdeptVision™ can... and does.

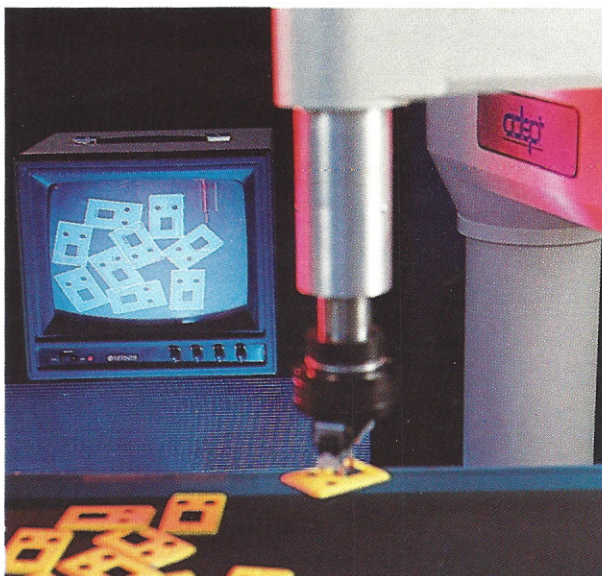
Real time vision, real time reaction.

AdeptVision communicates with the robot controller quickly because it communicates directly... in the same language... without any of the integrating hardware and software that slows other systems down and drives installation costs up.

In other words, AdeptVision comes fully integrated with the Adept robot system, and the result is sheer speed. In both its area and moving line versions, AdeptVision identifies and locates up to six parts per second — and communicates the information fast enough to guide the robot's path in real time.

Simplicity plus brainpower.

Most vision systems require special software for each part they handle. And most vision companies don't tell you



that. This can burn up several man-months of an expensive programmer's time and delay your start-up significantly.

AdeptVision requires no part-specific software. It's ready to go the day you install it and requires only about 15 minutes of training per part.

What's more, because AdeptVision identifies significant part features instead

of the entire part area, it accomplishes more with less raw data. And then turns it into real time robot guidance information with powerful 68000 processors.

Touching and overlapping parts.

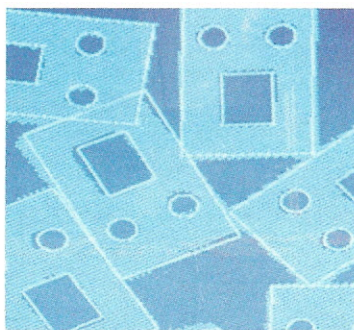
Most vision systems can't identify parts the way they're presented in real life: randomly oriented, touching, or even overlapping. AdeptVision can, because its unique algorithms work with part features instead of areas.

This flexible parts presentation ability can save you a fortune in hard tooling costs

now... and later on when you change product mix or design.

Seeing is believing.

We'd like to show you AdeptVision in action... at an Adept-equipped systems integrator near you. Just give us a call, and we'll make the arrangements. In the meantime, we'll mail you all the details. Just contact Adept Technology, Inc., 1212 Bordeaux Drive, Sunnyvale, California 94089. Phone: (408) 747-0111. TELEX: 171942.



AdeptVision™ quickly identifies randomly oriented, touching, or overlapping parts.



adept™
adept
technology, inc.

Robots that work.